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Characterization of Operating and Maintenance Practices for Wastewater Treatment Systems in the Iron and Steel Industry

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16. ABSTRACT The report documents effective operating and maintenance (O/M) practices for wastewater treatment systems in the iron and steel industry, and describes how their application might affect permit parameters and operational upsets. Selection of processes for the study--byproduct cokemaking, ironmaking (blast furnaces), steelmaking (basic oxygen furnaces), hot forming, and acid pickling--was based on pollutant loadings, system complexity, control costs, and commonality among most integrated steel mills. Information was based on: a literature search for wastewater-related O/M practices in the iron and steel industry, discussions with state and regional agency personnal to identify major areas of concern and effective O/M practices, a review of agency files, discussions with wastewater treatment equipment vendors and chemical additive manufacturers, and discussions with agency representatives. Various steel mills were visited, and treatment plant operators and environmental staff members were interviewed. The information produced by these visits includes typically encountered problems and their solutions, troubleshooting efforts, extent of operator training, efforts to minimize the effect of operational upsets, and preventive maintenance practices.

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Iron and Steel Industry		Stationary Sources	11F
Waste Water	Hot Working	Operating Procedures	
Water Treatment	Basic Converters	Basic Oxygen Furnaces	
Maintenance	Oxygen Blown Converters	Acid Pickling	15E
Coking			13H
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by

PEDCo Environmental, Inc.
11499 Chester Road
Cincinnati, Ohio 45246

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Project Officer

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Industrial Process Branch

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SECTION 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

This report presents the results of a study of operating and maintenance (O&M) practices for wastewater treatment systems in the iron and steel industry. The purpose of the study is to document effective O&M practices and how their application might affect permit parameters and operational upsets. The ultimate goal of the study, funded by the Industrial Environmental Research Laboratory (Research Triangle Park, North Carolina) of the Environmental Protection Agency, is an O&M characterization to assist both agency inspectors and plant personnel.

The wastewater generating processes selected for study were byproduct cokemaking, ironmaking (blast furnaces), steelmaking (basic oxygen furnaces), hot forming, and acid pickling. Selections were based on pollutant loadings, system complexity, control costs, and commonality among the majority of integrated steel mills.

Information was gathered from several sources: a literature search for wastewater-related O&M practices in the iron and steel industry, discussions with state and regional agency personnel to identify major areas of concern and effective O&M practices, review of agency files, discussions with wastewater treatment chemical additive manufacturers, and discussions with industry representatives.

A total of five steel mills, which included a total of 14 treatment systems, were visited (Table 1-1). Each plant visit lasted from 2 to 4 days, depending on the number of process treatment systems being studied. Treatment plant operators and environmental staff members were interviewed. Information gathering for a system lasted 1 or 2 days, depending on the complexity of the system and the availability of the operating personnel's

TABLE 1-1. PROCESS TREATMENT SYSTEMS STUDIED ON O&M WASTEWATER PROJECT

Plant	Coke plant[a]	Blast furnace[b]	Basic oxygen furnace[c]	Hot forming[d]	Acid pickling
1				X	
2	X	X	X	X	
3		X		X[e]	X[f]
4	X		X	X	X[g]
5	X	h	h	h	h

[a] The coke plants have biological treatment systems preceded by ammonia stills.

[b] The blast furnace systems have recycle loops.

[c] The BOF systems have recycle loops except for Plant 4, which is once-through.

[d] All of the hot forming operations were hot strip mills plus additional systems at Plant 3, as noted. Each of the hot strip mills utilized different treatment technologies:

Plant 1 - Ultra high rate filters
Plant 2 - Clarifiers
Plant 3 - Sedimentation basins
Plant 4 - Deep-bed filters

[e] Systems for treating wastewaters of the slabbing mill and continuous casters were also included in the study.

[f] This is a combined hydrochloric acid pickling/cold rolling treatment system.

[g] The plant trip for pickling primarily involved acid regeneration (HCl)

[h] Combined treatment.

time. The information produced by these visits includes typically encountered problems and their solutions, troubleshooting efforts, extent of operator training, efforts to minimize the effect of operational upsets, and preventive maintenance practices. Forms used during the interviews were developed to serve as a guide in collecting consistent information from the plants. Some of the forms request information on treatment component design. Certain design information was felt to be important in comparing system design details (e.g., gpm/ft^2 for clarifiers (thickeners). The information collected could be recollected by operators and their supervisors and it was readily available from plant O&M manuals. This information is used in Sections 3 and 4. The forms are contained in Appendix A.

The report is intended to provide a better understanding of wastewater problems in the iron and steel industry, to help agency inspectors to be more effective in evaluating the effect of O&M practices on wastewater treatment performance, and to provide information to apprise plant personnel of practical and cost-effective O&M practiced by others in their industry in the proper operation of their treatment systems.

We are not concerned here with regulatory issues; e.g., we do not consider treatment equipment in the context of Best Practicable Technology (BPT) or Best Available Technology (BAT), but rather as operating hardware that should operate efficiently with minimal downtime.

1.2 RATIONALE

The steel industry, one of the largest industrial users of water, uses about 20,000 to 40,000 gallons per ton of steel produced. The bulk of this usage is for noncontact cooling; however, significant amounts of water are used in the manufacturing processes and must be treated prior to discharge.

The BPT and BAT for steel mill process wastewaters have been defined in the Final Development Documents for Effluent Limitations Guidelines for the Iron and Steel Manufacturing Point Source Category. Many plants have installed equipment to meet these limitations.

The iron and steel manufacturing industry has been subjected to extensive study in the development of proposed effluent limitation guidelines. By and large, EPA's Effluent Guidelines Division has not addressed operation and maintenance, inspection, or continuous compliance; instead, it has been technology-oriented for the purpose of setting standards.

Pollutants that must be treated in iron and steel wastewater include total suspended iron, zinc, chromium (total, hexavalent, and dissolved), lead, tin, fluoride, nickel (total and dissolved), dissolved copper, cadmium, oil and grease, ammonia-nitrogen, phenols, and others. The pH of the wastewater also must be controlled. The pollutants occur in various wastewaters as a result of the following: process water contact with the fuel (coke), the input or output metals, and finishing processes such as rolling, pickling, galvanizing, and others.

Many different treatment systems are used to meet current guidelines. These vary by subcategory. Primary treatment systems rely on such physical/chemical methods as neutralization, sedimentation, flocculation, and filtration. Coke plant wastewater treatment involves the use of biological oxidation, carbon adsorption, ion exchange, evaporation, and others. Table 1-2 presents the major categories of pollutants and their corresponding generic treatments. Table 1-3 shows a summary of most of the major treatment technologies used in the iron and steel industry to meet current permit limits. In addition to these methods, various in-plant modifications can be made to reduce the pollutant loading.

TABLE 1-2. TREATMENTS AVAILABLE IN IRON AND STEEL INDUSTRY

Pollutant type	Treatment methods
Solids	Settling lagoon (basin) Clarification Filtration
Oil and grease	Skimming Filtration Floatation
Metals	Chemical precipitation Filtration
Organics	Carbon adsorption (not prevalent) Biological oxidation
	Ion exchange[a] Reverse osmosis[a]

[a] Advanced technologies.

TABLE 1-3. SUMMARY OF MAJOR WASTEWATER TREATMENT TECHNOLOGIES USED IN THE IRON AND STEEL INDUSTRY

Treatment components	Subcategory				
	Cokemaking	Ironmaking	Steelmaking	Hot forming	Acid pickling
Clarifier/thickener	x	x	x	x	x
Vacuum filter	x	x	x	x	x
Filtration (general)	x	x	x	x	
Recycle system	x	x	x	x	x
Lime/caustic addition system	x	x	x		
Acid neutralization	x		x		
Settling basin	x	x		x	x
Aeration	x				x
Bioxidation	x				
Quench tower[a]	x				
Free/fixed ammonia stills	x				
Polymer addition system	x	x	x	x	x
Cooling tower	x	x	x	x	
Alkaline chlorination		x			
Inclined plate separator			x		
Oil skimmer	x	x		x	x
Scale pit				x	
Deep bed pressure filter				x	
Cascade rinse					x
Oil cracking and recovery[b]				x	
pH control	x	x	x		x

[a] Evaporation to extinction, not permitted in many states.

[b] For cold mill rolling oil in central treatment systems.

The effluent guidelines define 12 subcategories for integrated steel plants, as shown in Table 1-4. Within these subcategories is a wide variety of processes, but the general character of the wastewaters from the processes within a subcategory is similar. The information presented in Table 1-4 indicates the following:

- Cokemaking and ironmaking are the dominant sources of organics.
- Ironmaking, steelmaking, hot forming, and acid pickling are the dominant sources of metals.
- Ironmaking and hot forming have the highest discharge flow rates.
- Five of the subcategories represent 95 percent of conventional pollutant loadings: sintering, ironmaking, steelmaking, hot forming, and cold forming.

These subcategory characteristics are important in selecting processes for the O&M study. If malfunctions and upsets occur, they presumably lead to excess discharge levels. Consequently, processes with toxic components are of greater interest. Processes with high discharge flow rates are important because upsets will lead to higher gross discharges. Also, high flow rates generally mean higher maintenance costs. The following is a complete listing of the selection criteria.

- Capital and annual cost of treatment
- Flow rate
- Organic pollutant loading
- Metals pollutant loading
- Conventional pollutant loading
- Number of installations
- Complexity of effluent limitations (number of pollutants)
- Recycle requirements
- Complexity of treatment scheme
- Continuous operation of process
- Ongoing process or likelihood of phase-out (This criterion eliminates the open hearth process from the steelmaking subcategory and the beehive process from the cokemaking subcategory.)
- Difficulty in achieving compliance

TABLE 1-4. FLOW AND RAW LOADINGS FOR THE TWELVE IRON AND STEEL SUBCATEGORIES[1]

Subcategory	Discharge flow, 10^3 gal/day	Effluent loadings, tons/year		
		Toxic organics	Toxic metals	Others
A. Cokemaking	36.9	26,306.0	151.6	76,082
B. Sintering	122.6	84.0	616.0	1,185,500
C. Ironmaking	1,036.8	20,088.0	41,280.0	3,029,860
D. Steelmaking	284.4	15.5	25,130.2	1,274,460
E. Vacuum degassing	57.1	0	976.0	6,955
F. Continuous casting	238.0	0	590.5	30,791
G. Hot forming	4,188.0	0	34,820.0	6,289,895
H. Scale removal	0.9	0.2	375.6	1,387
I. Acid pickling	172.7	4.6	31,918.0	615,548
J. Cold forming	87.3	279.7	186.4	2,106,264
K. Alkaline cleaning	2.9	0.2	0.8	1,583
L. Hot coating	34.7	2.3	3,447.0	7,088

To evaluate these criteria objectively and quantitatively, a rating system was utilized to assign a numerical value or score for each in a process-criteria matrix. The results of this scoring are shown in Figure 1-1. The scoring system is described below. The scoring basis for each criterion is such that a higher score means the process is more important for consideration.

Capital Cost (Ref. 1, p. 13)

Basis: In-place and required capital (7/1/78 dollars)

Scoring: 0 - 10^6 = 1
10.1 - 100 2
100.1 - 200 3
etc.

Annual Cost (Ref. 1, p. 13)

Basis: Total annual cost (7/1/78 dollars)

Scoring: 0 - 10^6 = 1
10.1 - 20 2
20.1 - 30 3
etc.

Raw Toxic Organics Load (Ref. 1, p. 14)

Basis: Total tons/year raw toxic organics

Scoring: 0 - 100 = 1
101 - 200 2
↓
>1000 11

Raw Toxic Metals Load (Ref. 1, p. 14)

Basis: Total tons/year raw toxic metals

Scoring: 0 - 1000 = 1
1001 - 2000 2
↓
>10,000 11

Conventional Pollutant Load (Ref. 1, p. 14)

Basis: Total tons/year

Scoring: 0 - 10^6 = 1
>1 - 2 x 10^6 = 2
>2 - 3 x 10^6 = 3
etc.

Subcategory	Capital cost	Annual cost	Organics	Metals	Pollutant load	Number of pollutants	Treatment complexity	BAT recycle	Number of plants	Water usage	Continuous operation	Total	Overall rating
Cokemaking	5	11	11	1	1	9	11	1	6[a]	2	3	61	3
Sintering	2	4	1	1	2	9	10	6	3	3	2	43	6
Ironmaking	6	10	11	11	4	10	10	9	6	11	3	91	1
Steelmaking	3	4	1	11	2	4	8	6[b]	5	4	2	50	5
Vacuum degassing	2	1	1	1	1	4	3	9	4	2	1	29	11
Continuous casting	3	3	1	1	1	5	4	10	5	4	2	39	8
Hot forming	8	11	1	11	7	3	5	7	11	11	1	76	2
Scale removal	1	1	1	1	1	4	9	7	3	1	1	30	10
Acid pickling	5	7	1	11	1	4	8	7	10[c]	3	1	58	4
Cold forming	2	2	3	1	3	9	6	1	11	2	1	41	7
Alkaline cleaning	2	1	1	1	1	3	5	1	4[c]	1	1	21	12
Hot coating	2	2	1	4	1	6	5	1	8	2	1	33	9

[a] Excluding beehive.

[b] BOF only.

[c] Continuous only.

Figure 1-1. Process criteria scoring matrix.

Number of Regulated Pollutants (Ref. 2, p. 23283-23284)

Basis and scoring: Number

Treatment Complexity (Ref. 1, p. 26-29)

Basis and scoring: Number of BPT and BAT treatment components

Recycle Requirement (Ref. 1, p. 26-29)

Basis: Percent recycle at BAT

Scoring:
0 - 90 = 1
91 = 2
92 = 3
etc.

Number of Plants (Ref. 1, p. 58-60)

Basis: Number of plant sites

Scoring:
0 - 10 = 1
11 - 20 = 2
↓
>100 = 11

Water Usage (Ref. 1, p. 14)

Basis: Raw discharge flow in millions of gallons per day

Scoring:
0 - 10 = 1
10.1 - 100 = 2
100.1 - 200 = 3
↓
>900 = 11

Continuous Operation (Based on PEDCo experience)

Scoring:
Process operates continuously, very difficult to shut down - 3

Process typically has some periodic shutdowns - 2

Process typically is operated with scheduled shutdowns - 1

Based on the scores in Figure 1-1, the subcategories of greatest interest, i.e., those with highest pollutant loadings, greatest complexity, and highest control cost, are:

1 - Ironmaking
2 - Hot forming
3 - Cokemaking
4 - Acid pickling
5 - Steelmaking

1.3 CONCLUSIONS

The general positive highlights of the plants visited are the high degree of operator know-how and job interest, the high degree of system monitoring to maintain performance, apparent concern and interest in pollution control, good attention to visual inspections, well-staffed departments, and cooperative attitude and willingness to share information. Most of the systems at the plants appeared to be well designed. Such systems in combination with effective O&M practices are required for a well-operated plant.

The general areas of concern are lack of communication between process operators and water treatment operators; competition between treatment plant and production processes for maintenance resources; performance of pH monitoring, on-line analyzers, and flow-measurement devices; hydraulic balance; excessive oil from rolling mills; high maintenance required on lime-based ammonia stills; debris in clarifiers/tanks/open-top containers; lack of detailed maintenance records; and lack of self audits.

1.4 ORGANIZATION OF REPORT

Section 2 of this report includes brief process descriptions of the steel processes considered and the basic treatment schemes as they relate to the process. For complete descriptions, the reference is made to various background documents and to the ninth edition of The Making, Shaping, and Treating of Steel. Pertinent process flow diagrams are included, however, to aid the reader in "visualizing" the sources of wastewater.

In Section 3, the major treatment components are described, with emphasis on upsets and the important O&M considerations of each type of equipment.

Section 4 describes the wastewater treatment on a system basis and includes the individual prices of equipment described earlier. The O&M considerations derived from the plant visits also are included in this section.

Section 5, which is devoted to monitoring and instrumentation, describes the hardware used and the attendant O&M problems. Monitoring of wastewater is critical to successful operation.

Section 6 covers the management practices required for effective operation. Included are organization, communication, staffing, training, and recordkeeping.

Section 7 summarizes the causes of upsets and the corrective actions needed, as derived from analysis of long-term NPDES self-monitoring data. The section also provides an overall summary of effective O&M practices observed at steel mills.

REFERENCES FOR SECTION 1

1. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. I. EPA 440/1-80/024-b, December 1980.

2. U.S. Environmental Protection Agency. Iron and Steel Manufacturing Point Source Category Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards. Federal Register, Vol. 47, No. 103. May 27, 1982.

SECTION 2

PROCESS DESCRIPTIONS

This section contains descriptions of the five major processes covered in this study. The basic process, wastewater sources, and characterization of the pollutant streams are presented only briefly to provide a framework and a background for the remainder of the report. More complete process descriptions can be found in several excellent references (e.g., Volumes II through VI of the Development Documents for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, or The Making, Shaping, and Treating of Steel). A complete review of wastewater sources and pollutant characterizations can be found in the background documents for the effluent guidelines in the iron and steel making segment.

2.1 COKEMAKING

Metallurgical cokemaking is an important part of the steel industry because it provides the fuel for the blast furnace. Since more than 99 percent of this coke is produced in byproduct coke ovens, beehive coke ovens are not discussed here.

The byproduct coke oven not only produces high quality coke for use in blast furnaces or foundries, it also recovers valuable byproducts such as coal tar, light oils, phenolates, ammonia compounds, naphthalene, and coke oven gas. These coke making operations take place in 59 locations in the United States.[1]

A byproduct recovery plant consists of batteries of ovens (generally consisting of 50 to 70 ovens) where coking coals are heated to drive off the volatile compounds of the coal in the absence of air. These volatile compounds are drawn off and recovered as byproducts. The residual remaining in the oven is coke. Coal is charged into narrow, rectangular, silica brick chambers, which are arranged side by side with a combustion chamber in between to provide the indirect heat. The typical coking time is 18 hours. After the coking cycle is over, the coke is pushed out into a coke car, which is quenched with water at the quench tower. The quenched coke is further screened and sent to blast furnaces. Figure 2.1-1 shows the coke and byproduct recovery stages in a typical byproduct coke oven plant.

As the destructive distillation of coal continues in the coking process, the generated raw gas is cooled with flushing liquor. The gas then goes to the primary coolers, where the tar is separated out. The flushing liquor goes through a decanter for removal of any remaining tar, and this liquor is recycled to the collecting main. The moisture in coal, typically around 6 percent, is vaporized during coking and condenses in the collecting main by the liquor spray, thus creating excess liquor. Excess ammonia liquor is withdrawn and sent to the wastewater treatment plant. This highly contaminated water absorbs many organic constituents, as well as ammonia and solids, from the gas. The gases continue through a tar extractor, ammonia absorber, final cooler, and gas scrubber. The tar extractor removes any residual tar, and the absorber absorbs the ammonia with the acid. The final coolers separate the crude naphthalene from the gas, and the wash oil sprays in the gas scrubber remove the benzol. At some plants, the gas then passes

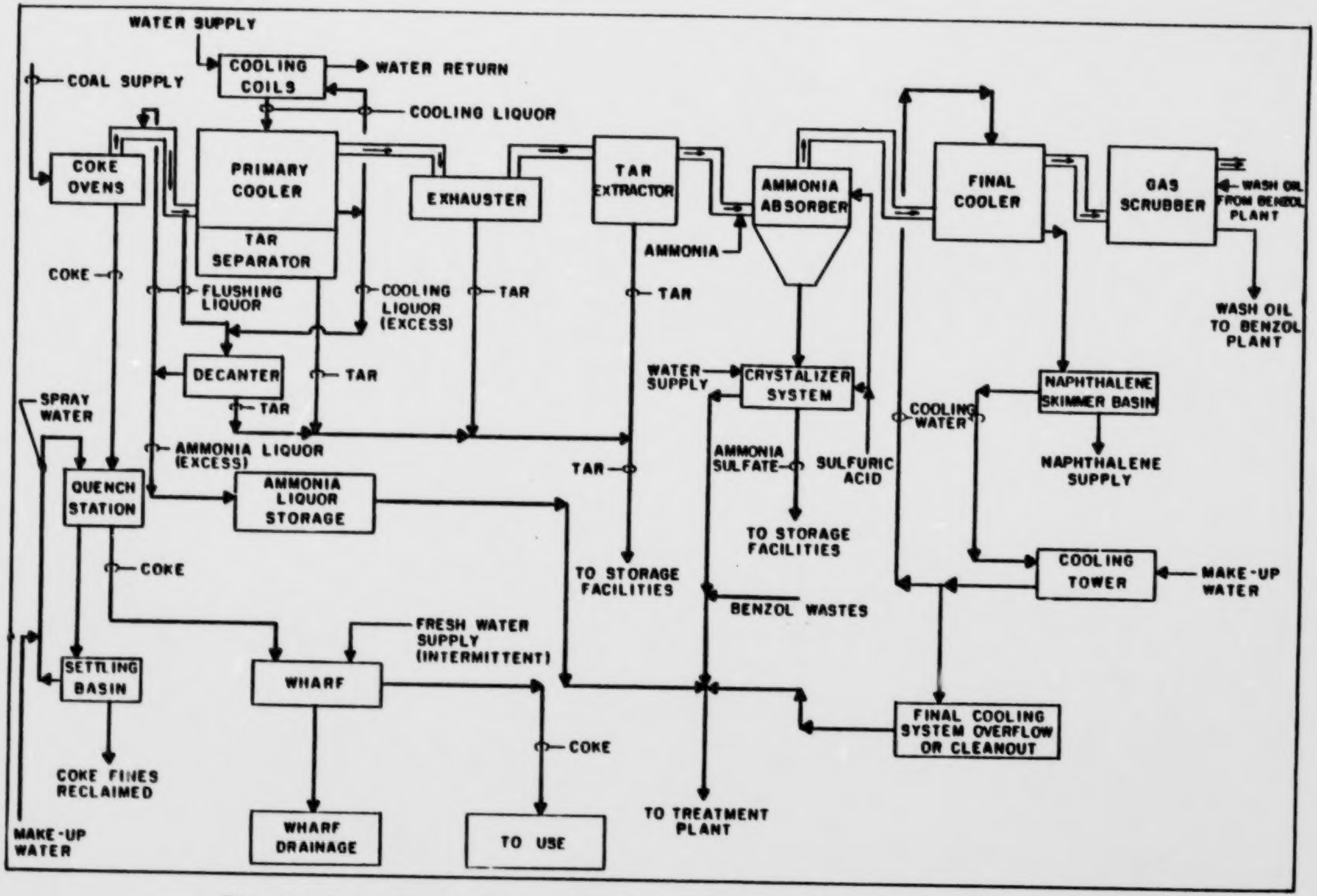

WATER SUPPLY
COAL SUPPLY
COOLING COILS
WATER RETURN
COOLING LIQUOR
COKE OVENS
PRIMARY COOLER
TAR SEPARATOR
EXHAUSTER
TAR EXTRACTOR
AMMONIA ABSORBER
FINAL COOLER
GAS SCRUBBER
WASH OIL FROM BENZOL PLANT
WASH OIL TO BENZOL PLANT
COKE
FLUSHING LIQUOR
COOLING LIQUOR (EXCESS)
TAR
TAR
TAR
AMMONIA
DECANTER
TAR
TAR
WATER SUPPLY
CRYSTALIZER SYSTEM
COOLING WATER
NAPHTHALENE SKIMMER BASIN
NAPHTHALENE SUPPLY
SPRAY WATER
AMMONIA LIQUOR (EXCESS)
TAR
AMMONIA SULFATE
SULFURIC ACID
QUENCH STATION
AMMONIA LIQUOR STORAGE
TO STORAGE FACILITIES
COOLING TOWER
MAKE-UP WATER
COKE
TO STORAGE FACILITIES
BENZOL WASTES
FRESH WATER SUPPLY (INTERMITTENT)
SETTLING BASIN
WHARF
FINAL COOLING SYSTEM OVERFLOW OR CLEANOUT
COKE
COKE FINES RECLAIMED
TO TREATMENT PLANT
MAKE-UP WATER
WHARF DRAINAGE
TO USE

Figure 2.1-1. Block diagram showing coke plant operations.
Source: Reference 1.

through a desulfurization process before it is finally used as coke oven underfire or as fuel in other steelmaking processes.

2.1.1 Wastewater Sources and Flow Rates

The most significant wastewaters from byproduct cokemaking and byproduct recovery operations are waste ammonia liquor; final cooler wastewater; light oil recovery wastewaters; barometric condenser wastewaters; contaminated wastewaters from air pollution scrubbers for the charging, pushing, and preheating processes; and water from desulfurization operations. Additional miscellaneous wastewaters are generated by coke wharf drainage, quench sump overflows, and coal or coke pile runoffs. The character of all these wastewaters is similar in that they all contain coal-based contaminants resulting from their contact with organic gases and solids.

The volume of excess ammonia liquor varies from 18 to 103 gal/ton of coke at plants using semidirect ammonia recovery, and from 62 to 106 gal/ton at plants using direct recovery.[1] Final cooler wastewater, which originates from direct-contact cooling of coke oven gas, ranges from 46 to 197 gal/ton, but this volume is reduced by recycling to a range of 2 to 10 gal/ton.[1] Nearly 70 percent of the byproduct coke plants have some wastewater from this source. Wastewater from light oil recovery (benzol plant) varies widely in volume depending on the degree of recovery and whether recirculation is practiced. With recirculation the range is 11 to 128 gal/ton.[1] These are the three most common sources of wastewater in byproduct plants.

In some plants, the final cooler wastewaters and benzol plant wastewaters are used as makeup water along with fresh water for quenching of coke. The typical amount used for this purpose is 500 gal/ton. About one-third (150 gal/ton) of this water is evaporated. The runoffs are collected in a sump and recycled.

Coke plant wastewaters from these various sources, which average 50 to 250 gal/ton of coke, are usually difficult to treat because of the many different contaminants they contain. Current treatment technologies are complex and sensitive to operating variables. Many factors influence the choice of wastewater control and treatment alternatives. Depending on the extent of recovery it provides, the byproduct recovery system itself will reduce the load of wastes in the wastewaters. The following recovery and treatment methods (and combinations thereof) are currently used:

- Recovery of free ammonia from excess ammonia liquor.
- Dephenolization of weak ammonia liquor and benzol plant wastes.
- Sedimentation of dephenolized wastes and miscellaneous wastewaters in a settling pond.
- Recycling of wastewater as coke quench waters to extinction.
- Single-stage or multiple-stage biological treatment.
- Physical/chemical treatments using activated carbon columns.

The plants visited during this study used biological treatment systems. Their arrangements are discussed in Section 4.1.

2.1.2 Pollutant Characterization

Coke plant wastewaters contain high concentrations of toxic pollutants. A total of 40 toxic organic pollutants and 11 toxic metal pollutants were found to be present in coke oven wastewaters. Coke plants are classified as one of the largest sources of toxic pollutants. The wastewaters contain suspended solids, ammonia-N, cyanides, phenolic compounds, sulfides, oil and greases, acids, and many toxic organic and inorganic pollutants. Table 2.1-1 shows some raw waste analyses. The effluent limitations for BPT and BAT are as follows.

	Daily maximum, lb/ton coke	
	BPT	BAT
TSS	0.506	
O&G	0.0654	
Ammonia-N	0.548	0.1086
Cyanide	0.1314	0.01276
Phenols (4AAP)*	0.0090	0.00013
pH	6-9	
Benzene		0.0000638
Naphthalene		0.0000638
Benzo(a)pyrene		0.0000638

*4AAP = 4-aminoantipyrine.

TABLE 2.1-1. NET CONCENTRATIONS OF POLLUTANTS IN MAJOR COKE PLANT WASTEWATER STREAMS[1]

Reference code	Excess ammonia liquor			Final cooler blowdown	Benzol plant wastewater	
	0868A	0920F	0684F	0732A	0920F	0684F
Flow, gal/ton coke	27.8	32.5	47.0	70.5	23.4	49.7
Pollutant concentration, mg/liter:						
Suspended solids	80	44	97	29	95	75
Oils and greases	184	172	83	28	38	166
Ammonia (N)	2387	4375	8255	30	366	187
Sulfide	439	908	976	22		79
Thiocyanate	592	659	680	52	264	239
Phenolic compounds	626	1172	1715	101	127	455
pH (units)	9.6-9.8	8.8-8.9	8.6	7.3	7.8	8.4
Benzene	27.2	5.2	3.4	37.3	74.5	85.5
Naphthalene	28.9	35.3	27.5	39.0	5.3	27.5
Phenol	327	413	120	59.7	75.8	40.0
Toluene	8.9	2.1	0.44	17.0	10.1	11.5
Cyanide	22.3	28.6	25.9	188		1.025

ND = None detected.

Note: Net concentration means that the concentrations of the wastewaters shown include only the pollutants contributed by the given operations. They do not include intake, or background concentrations to the operations.

The daily average limitations range from 30 to 55 percent of the daily maximum allowances depending on the pollutant. There are no daily averages for benzene, naphthalene, or benzo(a)pyrene.

The composition of the raw waste is influenced by the coal used and coking time. The quantity of waste ammonia liquor is a function of the coal surface moisture and the combined water in the coal. The quantity of liquor is generally 40 to 50 gallons per ton of coal.[2]

The model for BPT consists of a fixed ammonia still, settling basin, acid neutralization system, single-stage bioxidation, and a clarifier (with vacuum filtration of underflow). The model for BAT includes extended bioxidation (i.e., second-stage biological reactor), a clarifier, and a subsequent filter.

REFERENCES FOR SECTION 2.1

1. U.S. Environmental Protection Agency. Development Document for Effluent Limitations. Guidelines and Standards for the Iron and Steel Manufacturing Industry. Point Source Category, Vol. II, Coke Making Subcategory. EPA-440/1-82-024, May 1982.

2. Jablin, R., and G. P. Chanko. A New Process for Total Treatment of Coke Plant Waste Liquor. Presented at AIChe Seminar on the Advances in Industrial Waste Pollution Control, New York City, November 26-30, 1972.

2.2 BLAST FURNACE

In the U.S. steel industry there are 128 blast furnaces that are either active or on temporary shutdown.[1] This number represents a decrease from the more than 180 furnaces in use in the mid-seventies. This decrease has resulted from industry contraction and the replacement of multiple smaller furnaces with single large furnaces. Many smaller furnaces produce 1500 to 2000 tons/day, whereas the newest furnaces are designed to produce up to 10,000 tons/day. Water requirements, both for cooling and gas cleaning, are essentially proportional to the tons of iron produced.

Metallic iron is produced in the blast furnace from the reduction of iron oxide (in the form of ore, pellets, and sinter) by the carbon or carbon monoxide produced by burning coke. Heated air is blown through tuyeres into the side of the furnace, at the bottom, to provide the oxygen for burning the coke. Limestone or dolomite is added to form a molten slag that absorbs impurities such as sulfur and phosphorus. The furnace is cast about every 3 to 4 hours to drain the product metal and slag into receiving ladles. The newer large furnaces are cast almost continuously from multiple tapholes.

The products of combustion pass upward through the descending burden; thus the furnace is a countercurrent reactor. The top gas carries fine dust out of the furnace through a large cyclone (dust catcher) followed by a high-pressure venturi or adjustable orifice scrubber. Since the gas inherently has significant potential energy (2 to 35 psi) imparted by the blower, high-pressure drop scrubbers can be used without the energy penalty normally associated with gas cleaning. From the scrubber, the gas passes through a cooler and moisture separator and on to the distribution mains for use as a byproduct fuel. Excess gas is flared or stored in a gas holder. The collected dust and dewatered scrubber sludge may be recycled through the sinter plant. Figure 2.2-1 shows the overall flow scheme of blast furnace operation and wastewater treatment.

The model discharge (blowdown) rates for blast furnace recirculation systems are 125 gal/ton for BPT and 70 gal/ton for BAT.

In the sintering process, fine iron ore, waste dusts, roll scale, fine lime, and coal fines or coke breeze are agglomerated so that these fines can be charged to the blast furnace. The materials are mixed with water (6 to

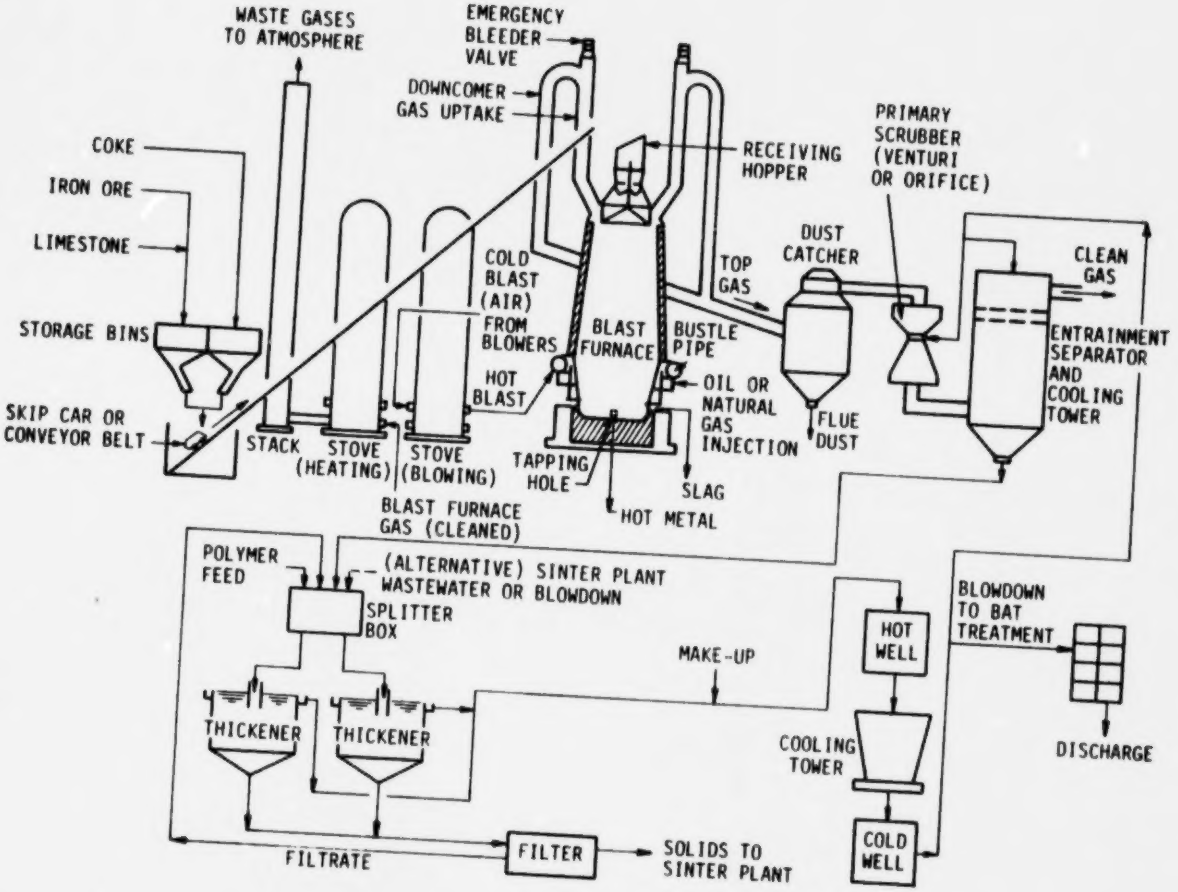

WASTE GASES TO ATMOSPHERE
EMERGENCY BLEEDER VALVE
DOWNCOMER
GAS UPTAKE
COKE
IRON ORE
LIMESTONE
RECEIVING HOPPER
PRIMARY SCRUBBER (VENTURI OR ORIFICE)
DUST CATCHER
TOP GAS
CLEAN GAS
COLD BLAST (AIR) FROM BLOWERS
BLAST FURNACE
BUSTLE PIPE
STORAGE BINS
ENTRAINMENT SEPARATOR AND COOLING TOWER
HOT BLAST
OIL OR NATURAL GAS INJECTION
FLUE DUST
SKIP CAR OR CONVEYOR BELT
STACK
STOVE (HEATING)
STOVE (BLOWING)
TAPPING HOLE
SLAG
HOT METAL
BLAST FURNACE GAS (CLEANED)
POLYMER FEED
(ALTERNATIVE) SINTER PLANT WASTEWATER OR BLOWDOWN
SPLITTER BOX
BLOWDOWN TO BAT TREATMENT
HOT WELL
MAKE-UP
THICKENER
THICKENER
COOLING TOWER
DISCHARGE
FILTER
SOLIDS TO SINTER PLANT
FILTRATE
COLD WELL

Figure 2.2-1. Example flow diagram of blast furnace operations and wastewater treatment.[2]

8 % moisture) and placed on a moving grate. An ignition hood ignites the coal or coke breeze. Air is drawn through the bed to continue the combustion process as the grate moves. The materials are fused together by incipient melting and are finally discharged as raw sinter. The product is crushed and screened to size for use as a blast furnace feed.

The air drawn through the bed is ducted to a scrubber (or dry gas cleaning device). Scrubber discharge water contains the same pollutants as blast furnace scrubber discharges, and cotreatment of the wastes is compatible. No sinter plant treatment systems were visited in this study.

2.2.1 Wastewater Sources and Flowrates

The major source of process wastewater in the blast furnace is the gas scrubbers used to clean the off-gas. Gas water seals at the stoves, gas coolers, scrubber moisture separators, and miscellaneous sources also contribute to the total flow. Discharge flow rates vary from less than 100 gal/ton for recycle systems to more than 6,000 gal/ton in once-through systems.[2] The treatment systems are physically large, their capacities ranging in size from 3,000 to over 10,000 gal/min.[2]

Although this study focuses on contaminated wastewater streams from the ironmaking process, an awareness of the noncontact water systems is necessary for the following reasons: they utilize O&M resources from the same pool of labor and supervision, the intake water systems are usually common for both process wastewater and cooling water circuits, and both circuits are often comingled in the outfalls.

The blast furnace is second only to the hot forming process in use of water in an integrated steel plant. Most of this water is noncontact cooling water used to cool the refractory lining and hearth of the furnace. Another major use of noncontact water associated with the blast furnace in most plants is to provide cooling and condenser water for the powerhouse. Together, these two flows amount to 24,000 to 30,000 gallons per ton of hot metal capacity. Because water usage does not decrease significantly during reduced operation, the water usage per ton increases.

The BPT model for treating blast furnace wastewater consists of flocculation and sedimentation by use of clarifiers or thickeners, polymer addition, vacuum filtration of underflow, and a recycling rate of 96 percent. Cooling towers are required in a tight recycling system to prevent temperature buildup. The BAT model requires an increase in the recycling rate to 98 percent and the addition of alkaline chlorination. Solids removal is relatively easy in blast furnace treatment systems. The areas of greater concern are the recycling rate and the control of ammonia, phenol, and cyanide.

The effluent limitations for the 30-day average are as follows:[3]

	BPT, lb/ton	BAT, lb/ton
TSS	0.052	0.052
Ammonia-N	0.107	0.00584
Cyanide	0.0156	0.000584
Phenols (4AAP)	0.0042	0.0000584
pH	6-9	6-9
TRC	-	a
Lead	-	0.000146
Zinc	-	0.000175
O&G	b	b

(Daily maximum limitations are three times the daily average.)

[a] Total residual chlorine daily maximum limitation is 0.000292 lb/day when chlorination is practiced.

[b] State water quality standards normally limit oil discharges to 10 to 15 mg/liter.

The above BPT loadings are based on 30-day average concentrations of pollutants as shown below:

Suspended solids	50 mg/liter
Ammonia-N	120 mg/liter
Total cyanide	15 mg/liter
Phenols	4 mg/liter

Sintering wastewater (or the blowdown from sinter plant recycling systems) is often cotreated with blast furnace wastewater because of the proximity of the sinter plant to the blast furnace and the similarity of the wastewater. The source of wastewater from sintering is wet air pollution control systems on the main sinter plant exhaust. There is no process water discharge from the sintering process per se.

The effluent limitations for the 30-day average from sintering are:[3]

	BPT, lb/ton	BAT, lb/ton
TSS	0.05	0.05
O&G	0.01	0.01
pH	6-9	6-9
Ammonia-N[a]	-	0.01
Cyanide[a]	-	0.001
Phenols (4AAP)[a]	-	0.0001
TRC	-	a
Lead	-	0.00025
Zinc	-	0.0003

(The daily maximum allowance is three times the daily average.)

[a] Applicable only when sintering wastewaters are treated with ironmaking wastewaters. Total residual chlorine daily maximum limitation is 0.0005 in this case.

If sintering and blast furnace waters are comingled, the allowable discharges are additive.

A detailed discussion of blast furnace wastewater treatment is described in Section 4.2.

2.2.2 Pollutant Characterization

Scrubber discharge water carries high suspended solids loadings. On a given furnace, this loading varies from hour to hour as the burden changes and casts take place. The water dissolves contaminants in the vapor phase, including ammonia, phenol, cyanide, and carbon monoxide. The water also dissolves alkalis (such as sodium and potassium), calcium, and magnesium from the dust. On furnaces in which oil is injected through the tuyeres, poor combustion conditions can lead to carbon black and unburnt oil leaving the furnace with the top gas. This will appear in the scrubber water discharge.

Raw wastewater characteristics are shown in Table 2.2-1.[2] Phenol and cyanide loadings are higher for furnaces burning coke that has been quenched with coke plant wastewater. The pH of blast furnace scrubber water is generally alkaline because it contains dissolved lime particles from the lime in the furnace charge. Sinter plant wastewaters contain lower phenol and cyanide concentrations. The pH is a function of the proportion of lime used in the sinter mix. Sinter plant off-gases also contain 100 to 500 ppm of SO_2, which tends to acidify the wastewater. On balance, most sinter plant discharges are alkaline. High oil contents are caused by the oils contained in mill scale and blast furnace flue dust and sludge.

TABLE 2.2-1. BLAST FURNACE AND SINTER PLANT RAW WASTEWATER CHARACTERISTICS[2]
(mg/liter, except as noted)

	Blast furnace	Sinter plant
Flow	3200 gal/ton	100-1400 gal/ton
Ammonia (as N)	2-227	5
Cyanide (total)	2-43	0-15
Phenols (4AAP)	0.1-8	0.2-2
Suspended solids	80-3560	550-5400
pH	6-12	5.2-12.7

REFERENCES FOR SECTION 2.2

1. Masleny, T. J., and P. D. Spawn. Blast Furnace Casthouse Control Technology - Fall 1987 Update. Proceedings: Symposium on Iron and Steel Pollution Abatement Technology for 1981.

2. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category. Volume II EPA 440/1-82-024, May 1982.

3. Federal Register. May 27, 1982. Vol. 47, No. 103.

2.3 BASIC OXYGEN FURNACE

Basic oxygen furnace (BOF) steelmaking, which is the predominant method for producing steel, accounted for more than 60 percent of total raw steel production in 1980.[1] The name is derived from the basic (dolomitic) refractory lining used in the vessels and the use of essentially pure oxygen for refining. The other methods for producing steel (open hearths and electric arc furnaces) were not considered in this study because they use relatively few wet control systems. Detailed process descriptions of the BOF are provided in several documents.[2,3,4] Only a brief overview is presented here.

A typical BOF shop consists of two vessels with facilities for handling the major raw materials, molten iron, scrap, and burnt lime. A few shops contain three vessels. The three major process variations are illustrated in Figure 2.3-1. These variations have relatively little effect on wastewater system O&M, but they do result in vastly different water flow rates.

Scrap and molten iron are charged through the mouth of the vessel in the approximate proportion of 25/75. Fluxes are added to produce a slag that absorbs the impurities in the metal, primarily sulfur and phosphorus. Pure oxygen is blown into the bath either through a lance from the top or through nozzles in the bottom of the vessel. This oxidizes the carbon and silicon in the molten iron, and the exothermic reactions provide all the energy for the process. In some cases, external fuel is used to enable more scrap to be melted.

The vessel is rotated to one side to receive the charge, and the steel product is drained out by tilting the vessel in the opposite direction. During blowing oxygen, the vessel is in an upright position.

Equipment is required for cleaning the gases produced by the furnace operation because large quantities of extremely small particles of dust are present in the gases. Dust composition varies with hot metal and scrap composition, but is essentially iron oxide.

The blowing cycle lasts 15 to 20 minutes, and the total heat cycle is about 45 minutes. Blowing does not take place during charging, tapping, testing, and related operations. Gas is generated only during the blowing period, although the induced-draft fans draw tramp air during nonblowing periods.

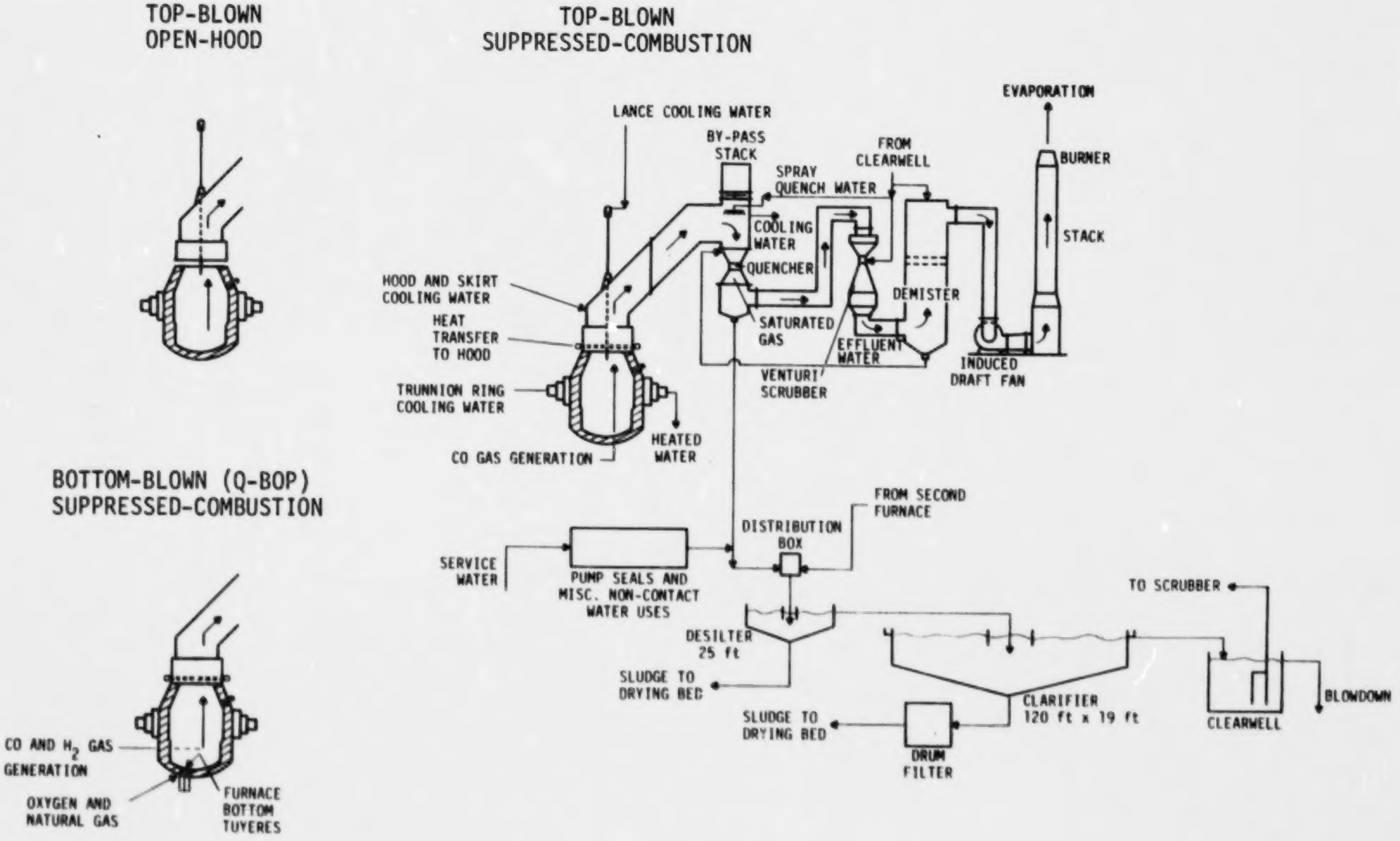

TOP-BLOWN
OPEN-HOOD
TOP-BLOWN
SUPPRESSED-COMBUSTION
BOTTOM-BLOWN (Q-BOP)
SUPPRESSED-COMBUSTION
CO AND H_2 GAS GENERATION
OXYGEN AND NATURAL GAS
FURNACE BOTTOM TUYERES
LANCE COOLING WATER
BY-PASS STACK
SPRAY QUENCH WATER
FROM CLEARWELL
EVAPORATION
BURNER
STACK
COOLING WATER
QUENCHER
DEMISTER
HOOD AND SKIRT COOLING WATER
HEAT TRANSFER TO HOOD
SATURATED GAS
EFFLUENT WATER
INDUCED DRAFT FAN
VENTURI SCRUBBER
TRUNNION RING COOLING WATER
HEATED WATER
CO GAS GENERATION
FROM SECOND FURNACE
DISTRIBUTION BOX
SERVICE WATER
PUMP SEALS AND MISC. NON-CONTACT WATER USES
TO SCRUBBER
DESILTER 25 ft
SLUDGE TO DRYING BED
CLARIFIER 120 ft x 19 ft
BLOWDOWN
CLEARWELL
SLUDGE TO DRYING BED
DRUM FILTER

Figure 2.3-1. BOF process variations for wet gas cleaning with example wastewater treatment system.[3]

Gas flow and, consequently, wastewater loading and temperature not only vary on a heat cycle basis, but the gas flow, dust loading, and temperature also vary widely during the blow itself. This variation in wastewater conditions is dampened by the retention time of the treatment system. No references have been found suggesting this variation presents a problem in BOF systems.

Figure 2.3-1 illustrates the essential features of both the gas cleaning and wastewater treatment systems for a BOF. The specific components and functions they perform are discussed in Sections 3.0 and 4.3.

As Table 2.3-1 shows, the United States has 37 BOF installations. In addition to totally dry control systems, three variations of wet control systems are used to clean the BOF off-gases. As the table indicates, there are 8 semi-wet systems and 7 dry systems. In the semi-wet systems, water is used to cool and condition the off-gas before it enters an electrostatic precipitator or a fabric filter. Because the effluent guidelines call for no discharge from these semi-wet systems, this study considers only the 22 installations that have wet systems using scrubbers. Only 2 of the 37 plants discharge to a POTW.

Two sub-categories have been established to recognize the differences between open-combustion systems and suppressed-combustion systems. In open-combustion systems, the hood used to collect the off-gas is positioned several feet above the furnace. The "open" space between the furnace top and the hood permits large quantities of air to be drafted into the hood. This air also provides oxygen to burn the carbon monoxide (CO) in the off-gas to carbon dioxide (CO_2) in the hood.

The suppressed-combustion system, which was introduced in the mid-sixties, has a movable skirt on the bottom of the hood that can be lowered to fit simply against the top of the furnace. This approach minimizes air infiltration and reduces the total gas flow rate into the control system. Because the CO is not burned in the suppressed-combustion system, the cleaned off-gas can be used as a fuel gas. (No systems in the United States currently recover the gas, however; it is flared.)

The two systems have some inherent differences. One such difference is the total gas volume that must be handled. Because the performance of a wet gas scrubber is not adversely affected by the presence of water droplets in the gas, sufficient water can be added at the quencher to assure cooling at

TABLE 2.3-1. BOF/Q-BOP WASTEWATER TREATMENT SYSTEMS[a]

Company	Location	Year installed	Furnaces		Capacity, million tons/yr	Type of gas cleaning system	Flow, gal/ton	
			Number	Size, tons			Applied	Discharge
Allegheny Ludlum Steel	Natrona, PA	1966	2	80	0.5	Wet-open	NA[b]	NA
Armco Steel	Ashland, KY	1963	2	180	2.0	Dry	NA	0
Armco Steel	Middletown, OH	1969	2	200	2.3	Wet-suppressed	1897	75
Bethlehem Steel	Bethlehem, PA	1968	2	270	3.5	Dry	NA	0
Bethlehem Steel	Burns Harbor, IN	1969	2	300	4.5	Wet-open	454	244
Bethlehem Steel	Burns Harbor, IN	1978	1	300	1.0	NA	NA	NA
Bethlehem Steel	Lackawanna, NY	1964/66	3	310	5.0	Wet-open	1824	1801
Bethlehem Steel	Sparrows Point, MD	1966	2	220	3.0	Wet-open	1315	437
CF&I Steel	Pueblo, CO	1961	2	118	1.4	Semi-wet	NA	NA
Ford Motor	Dearborn, MI	1964	2	240	3.8	Dry	NA	0
Inland Steel	East Chicago, IN	1966	2	255	6.7	Wet-open	977	99
Inland Steel	East Chicago, IN	1974	2	210		Wet-suppressed	1327	80
Interlake, Inc.	Chicago, IL	1959	2	78	1.1	Semi-wet	132	13[d]
Jones & Laughlin Steel	Aliquippa, PA	1968	3	207		Semi-wet	149	0
Jones & Laughlin Steel	Cleveland, OH	1961	2	220	3.0	Semi-wet	32	11
Jones & Laughlin Steel	East Chicago, IN	1970	2	290	3.0	Dry	NA	0
Kaiser Steel	Fontana, CA	1978	2	229	2.4	Wet-suppressed[e]	NA	NA
McLouth Steel	Trenton, MI	1958/59	5	120	2.8	Wet-suppressed	1818	1818
National Steel	Ecorse, MI	1962	2	300	5.8	Dry	NA	0
National Steel	Ecorse, MI	1970	2	230	NA	Dry	NA	0
National Steel	Granite City, IL	1968	2	235	2.5	Semi-wet	295	217
National Steel	Weirton, WV	1967	2	360	5.8	Wet-open	262	65
Republic Steel	Buffalo, NY	1970	2	130	1.0	Semi-wet	672	430
Republic Steel	Cleveland, OH	1966/77	2	220	3.7	Wet-suppressed	569	33
Republic Steel	Gadsden, AL	1965	2	150	1.5	Semi-wet	280	124
Republic Steel	So. Chicago, IL	1976	2 Q-BOP	225	2.3	Wet-suppressed	1129	113
Republic Steel	Warren, OH	1965	2	150	2.2	Semi-wet	184	52
Sharon Steel	Farrell, PA	1974	3[c]	150	1.6	Wet-open	1558	312
U.S. Steel	Braddock, PA	1972	2	220	2.5	Wet-open	241	241
U.S. Steel	Duquesne, PA	1963	2	220	2.5	Wet-open	1296	118
U.S. Steel	Fairfield, AL	1974/78	3 Q-BOP	200	3.5	Wet-suppressed	1046	113
U.S. Steel	Gary, IN	1965	3	215	8.0	Wet-open	1285	201
U.S. Steel	Gary, IN	1973	3 Q-BOP	200		Wet-open	1263	146
U.S. Steel	Lorain, OH	1971	2	225	3.0	Wet-suppressed	1278	39
U.S. Steel	So. Chicago, IL	1969	3	200	3.0	Wet-open	1946	1596
Wheeling-Pittsburgh Steel	Monessen, PA	1964	2	200	1.6	Dry	NA	0
Wheeling-Pittsburgh Steel	Steubenville, OH	1965	2	275	2.9	Wet-open	227	149

[a] Adapted from References 2 and 3.

[b] NA = not available.

[c] This facility consists of one standard top-blown BOF and two Kaldo units; the latter vessels are inclined and rotating during the oxygen blow. The Kaldo units have been virtually supplanted by the standard fixed unit.

[d] Blowdown used for dust control at slag processing operation.

[e] Reference 5.

high gas velocities. This in turn allows the ductwork to be streamlined so that the air drawn in at the mouth of the hood can be 110 to 170 percent of that theoretically required for combustion and still ensure against the accumulation of explosive mixtures. Because of the more stringent evaporation and temperature control limits, electrostatic precipitators, by contrast, must handle about 300 to 400 percent of theoretical air, or about twice the actual gas volume of a wet scrubber. The volume of a closed-hood, or partial-combustion, system is dramatically different--about one-eighth that of a dry cleaning system.

A further process distinction is the use of either a top-blowing (BOF) or a bottom-blowing (Q-BOP) steelmaking furnace. Actually, among the many permutations of oxygen blowing are side blowing with both top and bottom blowing (KMS process), blowing with oxygen and natural gas, and blowing powdered lime and/or inert gases for portions of the blowing cycle. None of these variations is recognized in the water discharge standards.

The effluent limitations for the 30-day average discharge from closed-hood (suppressed-combustion) systems are:[3]

	BPT (lb/ton)	BAT (lb/ton)
TSS	0.0208	0.0208
pH	6-9	6-9
Lead	-	0.000125
Zinc	-	0.000188

Effluent limitations for the open-combustion category are:

	BPT (lb/ton)	BAT (lb/ton)
TSS	0.0458	0.0458
pH	6-9	6-9
Lead	-	0.000276
Zinc	-	0.00041

The allowance for the maximum discharge for 1 day is 3 times the allowable 30-day average. The allowances for open systems are higher because of the higher discharge flow rates required.

The model discharge flow rate for open-combustion systems is 110 gal/ton; for suppressed-combustion systems, it is 50 gal/ton. For a typical plant producing 3 x 10^6 tons of steel per year, the limitations can be expressed in the more meaningful terms of concentration and total pounds/day.

Suppressed-combustion system (gpm = 285)

	Daily maximum		30-day average	
	mg/liter	lb/day	mg/liter	lb/day
TSS	150	513	50	171
Lead	0.3	1	0.1	0.33
Zinc	0.45	1.5	0.15	0.5

Open combustion system (gpm = 627)

	Daily maximum		30-day average	
	mg/liter	lb/day	mg/liter	lb/day
TSS	150	1129	50	376
Lead	0.3	2.2	0.1	0.7
Zinc	0.45	3.4	0.15	1.1

2.3.1 Wastewater Sources and Flow Rates

The sources of wastewater in the BOF process are the scrubber and the quencher used to cool and clean the vessel off-gases. In some installations, charging and/or tapping emissions are also ducted to the main scrubbing system. Waste gas from the BOF contains large quantities of dust, 20 to 50 lb/ton of steel.[6] The dust is primarily of various forms of iron oxides with lime, heavy metals, and some organics. In an open-combustion system, 90 percent of the particulates are of a submicron size, because combustion is more complete. By comparison, suppressed-combustion systems generate larger particles, of which only 30 to 40 percent are of submicron size. Because much of the heavier particulate matter remains in the furnace, the suspended solids loadings in the wastewaters from suppressed-combustion systems are much lower.[3] The lime particles give the water a high pH value. The liquid/gas ratio in most BOF scrubbing systems is 30 to 40 gal/1000 acfm. Most of this water is used to cool the gas. Table 2.3-1 presents applied and discharge flow rates in gallons/ton.

Although the details of the treatment systems naturally vary, the systems can be characterized by sedimentation and pH control. Polymers are added to aid in flocculation/clarification. Many systems have a first-stage cyclonic classifier or bowl desiltor (for removal of larger particles) followed by a thickener(s). Underflow sludge is usually dewatered with a vacuum filter. Blowdown is required because the water evaporated and carried off by the gas leaves behind all of its dissolved solids. At the same time the scrubbing water picks up and dissolves some of the solids in the gas stream, particularly lime and fluorides. One study suggests that control of calcium levels in the recycled water is the most critical factor limiting blowdown.[7]

Regardless of the kind of equipment used to clean BOF gas, there is one common result--a considerable quantity of solid material accumulates that must be removed and disposed of. A shop with an annual production of 3,000,000 tons of steel will recover up to 60,000 tons of dust. Treatment of BOF wastewater and O&M practices are discussed in detail in Section 4.3.

2.3.2 Pollutant Characterization

Table 2.3-2 presents the composition of nominal raw wastewater from open- and suppressed-combustion systems.[2] Concentrations will vary greatly according to the types of scrap used. Table 2.3-3 illustrates the variation reported by plants in an earlier study. Only two metals, lead and zinc, are regulated under BAT. Both of these are used as coatings on steel products and are introduced in the recycle scrap at plants producing lead- and zinc-coated products. They may also be present in purchased scrap. Because of their low melting points, both metals are volatilized in the process and find their way into the wastewater. Fluoride is introduced from the fluorspar used as a slag-forming agent in the process.

Limitations were considered for fluoride, but the Agency believes BAT treatment with lime precipitation will adequately control fluoride levels to 20 mg/liter.[3]

TABLE 2.3-2. RAW WASTEWATER CHARACTERIZATION
BASIC OXYGEN FURNACE

Parameter	Concentrations, mg/liter (except as noted)	
	Suppressed-combustion	Open-combustion
Suspended solids	1500	4200
Fluoride	15	15
pH	8-11 (units)	8-11 (units)
Cadmium	0.10	0.50
Chromium	0.50	5.00
Copper	0.25	0.50
Lead	15.00	1.00
Nickel	0.50	0.50
Silver	0.025	0.20
Zinc	5.00	5.00

TABLE 2.3-3. CHARACTERISTICS OF RAW WASTEWATER FROM THE BOF[7]

Plant	Suspended solids, mg/liter		Fluorides, mg/liter		pH	
	Range	Average	Range	Average	Range	Average
1		10,000				10.5
2	1,600-66,400	24,500			8.2-10.9	
3		9,804		57		8.2
4	900-8,000	3,500			10.0-12.0	11.0
5	28-29,953	4,618	3.3-30	22.4	3.8-12.6	10.3
6		2,276		76		9.6
7	1,330-2,900	2,184	36-44	39		9.8
8		6,000				10.5

REFERENCES FOR SECTION 2.3

1. American Iron and Steel Institute. Annual Statistical Report. Washington, D.C. 1980.

2. U.S. Environmental Protection Agency. Revised Standards for Basic Oxygen Process Furnaces - Background Information for Proposed Standards. Draft EIS. EPA-450/3-82-005a, January 1982.

3. U.S. Environmental Protection Agency. Effluent Guidelines Division. Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category. Vol. III. Washington, D.C. EPA-440/1-82-024, May 1982.

4. The American Institute of Mining, Metallurgical and Petroleum Engineers. Basic Open Hearth Steelmaking with Supplement on Oxygen in Steelmaking. 3rd Ed. New York, 1964.

5. Kaiser Steel Starts up Scrubber Effluent Cleaning System. Iron and Steel Engineer, May 1980.

6. Midwest Research Institute. Particulate Emission Factors Applicable to the Iron and Steel Industry. EPA-450/4-79-028, 1979.

7. Wong Chong, G. M., and S. C. Caruso. An Evaluation of the Treatment and Control Technology Recommended for the Basic Oxygen Furnace (BOF) Wastewaters. Carnegie Mellon Institute of Research, Pittsburgh, Pennsylvania. May 1977.

2.4 HOT FORMING

Hot forming is the steel forming process in which hot steel, initially in solid ingot form or in intermediate shapes, is reduced in cross section through a series of forming steps (generally hot rolling) for the ultimate production of finished and semifinished products (see Figure 2.4-1).

Primary Mills--

This is the initial rolling step used in the production of semifinished products such as blooms and slabs. Steel in ingot form, received after the molds are stripped, is charged into soaking pits (heating chambers), where the ingots are soaked uniformly to attain the hot rolling temperature. After soaking, the ingots are sent to the primary mill for a scale-breaking pass to break the thick scale formed during soaking. During this pass, high-pressure water removes the scale from the ingot surface. The ingot is further rolled to the desired bloom size (in a blooming mill) or to slab size (in a slabbing mill). Cooling water is continuously sprayed on the work rolls and the table rolls. After the desired cross section is rolled, the bloom or slab is cut to the desired length. Cooling water is used continuously to keep the equipment and rolls from spalling.

Flat Mills--

Slabs from the slabbing mill or continuously cast slabs generally serve as the starting material for flat products. After conditioning and inspection, the slabs are charged into continuous reheating furnaces. In hot strip mills, the slabs are reduced to a thickness of 0.04 to 1.25 in. Width generally ranges from 24 to 96 in. The hot slab first passes through a scale breaker and then through roughing stands and finishing stands, where the thickness is progressively reduced. The strip comes out of the last finishing stand at a rate of 2000 feet/minute and passes over a cooling table, where high-pressure water is directed onto the hot surface to control the finishing temperature. Coilers then coil the strip. The scale breaker water, rolling cooling water, and high-pressure strip cooling water flow through underground trenches (flumes) to settling chambers (scale pits) and then to the wastewater processing system.

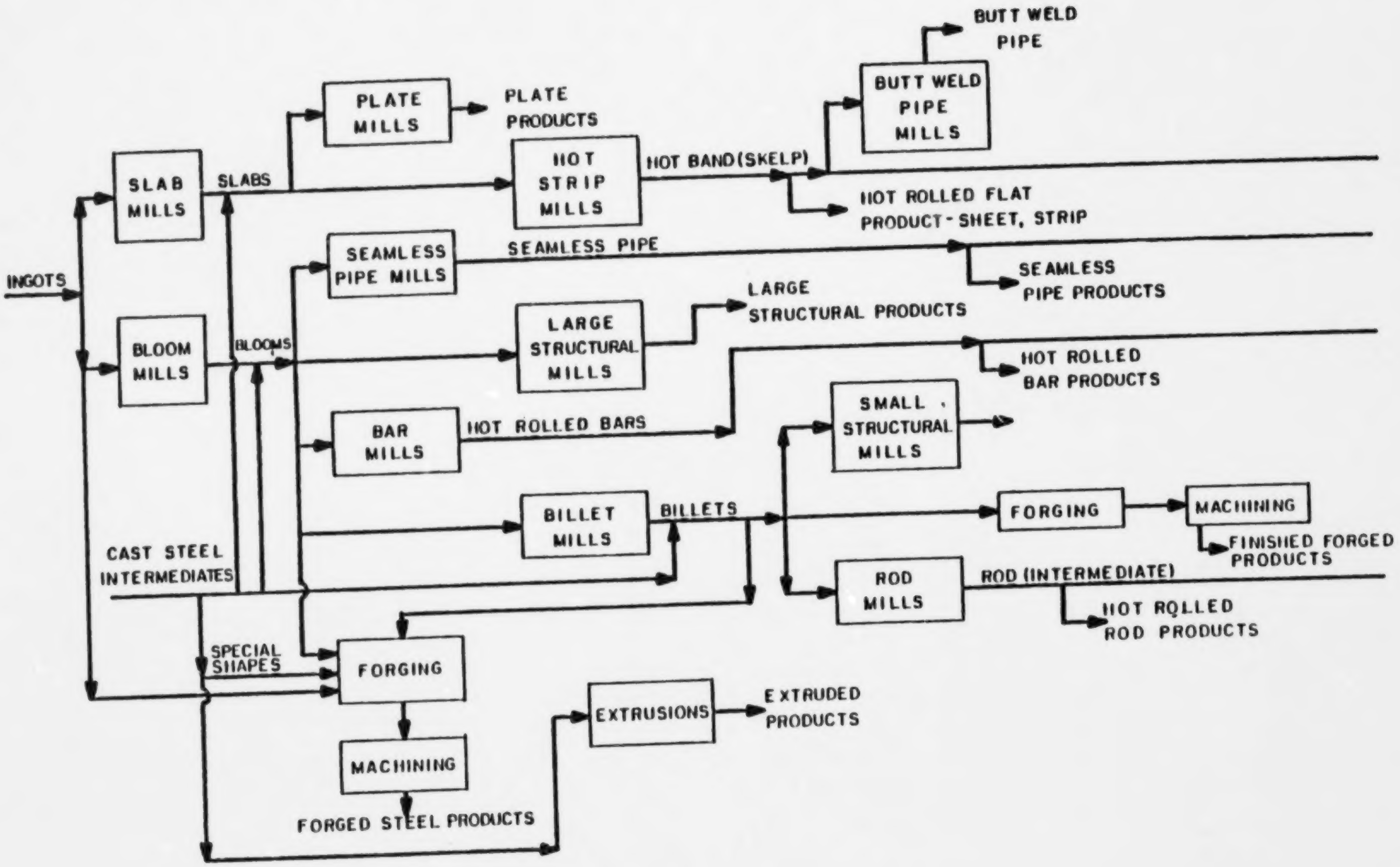

BUTT WELD PIPE
PLATE MILLS
PLATE PRODUCTS
BUTT WELD PIPE MILLS
SLAB MILLS
SLABS
HOT STRIP MILLS
HOT BAND (SKELP)
HOT ROLLED FLAT PRODUCT - SHEET, STRIP
SEAMLESS PIPE MILLS
SEAMLESS PIPE
SEAMLESS PIPE PRODUCTS
INGOTS
LARGE STRUCTURAL PRODUCTS
BLOOM MILLS
BLOOMS
LARGE STRUCTURAL MILLS
HOT ROLLED BAR PRODUCTS
BAR MILLS
HOT ROLLED BARS
SMALL STRUCTURAL MILLS
BILLET MILLS
BILLETS
FORGING
MACHINING
FINISHED FORGED PRODUCTS
CAST STEEL INTERMEDIATES
ROD MILLS
ROD (INTERMEDIATE)
HOT ROLLED ROD PRODUCTS
SPECIAL SHAPES
FORGING
EXTRUSIONS
EXTRUDED PRODUCTS
MACHINING
FORGED STEEL PRODUCTS

Figure 2.4-1. Block diagram showing hot forming operations.

Source: Reference 1.

Plate Mill--

Plates are generally flat hot-rolled finished products that fall into two size ranges: 1) more than 8 in. wide and generally 0.23 in. or more thick, and 2) more than 48 in. wide and at least 0.18 in. thick. The sequence of operations for plate mill rolling is reheating of slabs, descaling, rolling, leveling, cooling, and shearing. Generally a four-high reversing type of mill is used. Water is used for descaling and roll cooling. The difference in water quality between carbon and specialty rolling results from the characteristics of waste effluent produced due to the alloying elements present in specialty steels.

Pipe and Tube Mills--

Welded pipes are produced from hot-rolled strips. The strip width, which corresponds to the pipe circumference, is heated to welding temperature in a reheat furnace and is drawn through a die or roll pass and butt-welded. In electric resistance weld pipes, the strip is continuously fed into forming rolls, and the edges finally are welded by electrical resistance heating.

Noncontact cooling water is used for the reheating furnace and for forming and welding rolls. Contact cooling water is used at the cooling bed and at the descaler and sizing mills.

In seamless tubes, a hot solid round bar or billet is pierced with a mandrel as it passes through contoured rolls to form a hollow shell. This shell is further rolled in plug-type mills, where the diameter is expanded and the length increased. Noncontact water is used for the reheat furnace. Cooling water for rolls, mandrel, and tube cooling is collected and discharged to the scale pit.

2.4.1 Wastewater Sources and Flow Rates

All the hot rolling processes involve descaling steps in which high-pressure water is used. The work rolls and table rolls are cooled by low-pressure water. In reheating furnaces, noncontact water is used for cooling, and this water is also discharged to the mill wastewater system. The roll cooling water, the descaling water, and the mill scale fall into flumes located under the mills. These waters, along with the flume flushing water, discharge into scale pits (see Section 3.3). Scale pits often contain underflow weirs with launders to trap oil and grease picked up by the process waters. The waste oils are removed from the water surface by belts, ropes, or other types of floating oil skimmers (see Section 3.9). The scale is removed by clamshells or scale pit drag-link conveyors.

Although several different types of hot forming mills are in use, the hot forming processes have been grouped into one subcategory with the following major subdivisions:

a. Primary mills, carbon and specialty
   - i) Without scarfing
   - ii) With scarfing

b Section mills
   - i) Carbon
   - ii) Specialty

c. Flat mills
   - i) Hot strip and sheet mills, carbon and specialty
   - ii) Carbon plate mills
   - iii) Specialty plate mills

d. Pipe and tube mills
   - i) Carbon
   - ii) Specialty

Process wastewater originating in the hot forming processes must be treated before it is discharged to receiving waters or for recycle. Wastewaters from most mills in each of the hot forming subdivisions are treated in a central treatment system. Typical treatment technologies include sedimentation, clarification or filtration systems, and cooling through cooling towers. Flocculation with polymers or other flocculant aid is often used in conjunction with sedimentation. Extensive recycle systems are used at many plants. The degree of recycling that can be practiced at hot forming operations is controlled primarily by the product quality and temperature requirements of the process water.

The average overall process recycle rate for various operations, expressed as percentage, is as follows:[1]

Primary operations - 74.4%
Section operations - 84.6%
Flat operations - 71.2%
Pipe and tube operations - 73.5%

For better treatment systems the recirculation exceeds 96 percent.

The average applied flow rates per ton of product and the range for various categories is indicated below.[1]

Subcategory	Average applied flow rate, gal/ton	Range, gal/ton
Primary C and specialty[a] (without scarfing)	C - 2,250 gal/ton	250 - 6,750
	sp - 2,625 gal/ton	
Section mills	C - 5,100 gal/ton	130 - 14,900
	sp - 3,200 gal/ton	560 - 13,040
Flat mills - plates	C - 3,400 gal/ton	120 - 9,820
	sp - 1,500 gal/ton	140 - 8,800
Flat mills - hot strip	C - 6,380 gal/ton	720 - 22,940
	sp - 6,710 gal/ton	
Pipes and tubes	C - 5,490 gal/ton	450 - 16,000
	sp - 5,790 gal/ton	

[a] Carbon steel is designated by a "C" and specialty steel by "sp".

Of the plants visited, the treatment systems observed were those for hot strip mills and to a lesser degree, slabbing mills and continuous slab casters. These systems and applicable O&M practices are discussed in Section 4.4.

2.4.2 Pollutant Characterization

The wastewater characteristics of hot forming operations depend on scale formation and the oil usage within the mill. Suspended solids and oil and grease are the conventional pollutants found in hot forming operations. Toxic metal pollutants are also present to a lesser degree because of the use of alloying elements in steel. The suspended solids vary from 390 mg/liter for specialty operations to 7,590 mg/liter for carbon primary operations with scarfers. Oil and grease (O&G) in hot forming wastewaters varies from 15 to 160 mg/liter. Waste oils are generated at an average rate of 0.1 to 0.2 gallon per ton of steel at each rolling operation. Raw wastewater concentrations from hot-forming operations vary significantly; however, these variations are smaller after primary scale pit treatment, as shown below.[1]

	Concentration range of pollutants, mg/liter	
	Raw wastewaters	Discharge from primary scale pits
TSS	390 - 7,590	48 - 91
O&G	15 - 160	15 - 42

Toxic metals from both carbon and specialty mills can be reduced to similar levels if the same type of treatment is applied.

The latest BPT effluent limitations for various subcategories in the hot forming category are shown in Table 2.4-1. Since the BPT level of treatment provides adequate control both for conventional and toxic pollutants, EPA did not promulgate more stringent BAT limitations.

REFERENCES FOR SECTION 2.4

1. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Vol. IV. Hot Forming Subcategory. EPA-440/1-82/024. May 1982.

2. Environmental Protection Agency. Federal Register. Iron and Steel Manufacturing Point Source Category Effluent Limitations Guidelines, Pretreatment Standards, and New Source Performance Standards. Part II. May 27, 1982.

TABLE 2.4-1. BPT EFFLUENT LIMITATIONS FOR HOT FORMING[2]

Hot-forming subcategory	BPT effluent limitations				
	TSS, lb/ton		Oil and grease, lb/ton		
	Maximum for any day	Average of 30 consecutive daily values	Maximum for any day	Average of 30 consecutive daily values	pH
a. Primary mills, carbon and specialty					
i) Without scarfing	0.3	0.1122	0.0748	-	6 to 9
ii) With scarfing	0.442	0.166	0.1106	-	6 to 9
b. Section mills					
i) Carbon	0.714	0.268	0.1788	-	6 to 9
ii) Specialty	0.448	0.1682	0.1122	-	6 to 9
c. Flat mills					
i) Hot strip and sheet mills, carbon and specialty	0.854	0.32	0.214	-	6 to 9
ii) Carbon plate mill	0.454	0.1702	0.1136	-	6 to 9
iii) Specialty plate mill	0.20	0.0752	0.050	-	6 to 9
d. Pipe and tube mills, carbon and specialty	0.424	0.1590	0.106	-	6 to 9

2.5 ACID PICKLING

Pickling is a surface cleaning operation that uses acid to remove scale. During steel forming and finishing operations, the surface of the steel product becomes oxidized and oxide scale forms. This scale has to be removed before cold rolling operations and before the steel can receive a satisfactory protective coating (e.g., galvanizing or tinning). Scale removal is accomplished by immersing the steel into a bath of hot acid solution. Although several methods of scale cleaning are available, acid pickling has been widely adopted in the steel industry because of its low operating cost and ease of operation. Hydrochloric acid and sulfuric acid are generally used to pickle carbon steel products, whereas more than one acid is used for specialty steels. For example, nitric and hydrofluoric acids are typically used together when pickling stainless steel. Many combinations of acids are used, depending on the type of materials pickled. Temperature, agitation, acid concentration, and iron concentration in the bath are important factors in the pickling process.

Pickling can be conducted either as a batch process or in a continuous process. Figure 2.5-1 illustrates a typical continuous pickling line. Batch pickling is typically used for processing rods, bars, billets, pipes, and coiled wires. No batch pickling operations were considered in this study. Continuous pickling is used for flat-rolled coils and wire products. Regardless of the process used, the product has to be rinsed after pickling to remove all traces of acid. The acid fumes generated in the process are removed by the use of scrubbers or acid mist filters. In some cases, the used acid (spent acid) is recovered and regenerated (mostly H_2SO_4 and HCl).

The acid pickling category is further subdivided according to the type of acid used, the products pickled, and the type of wastewater discharged. These subdivisions are as follows:

- Sulfuric acid pickling
    - Strip, sheet, and plate products
    - Rod, wire, and coil products
    - Bar, billet, and bloom products
    - Pipe, tube, and other products
    - Fume scrubbers

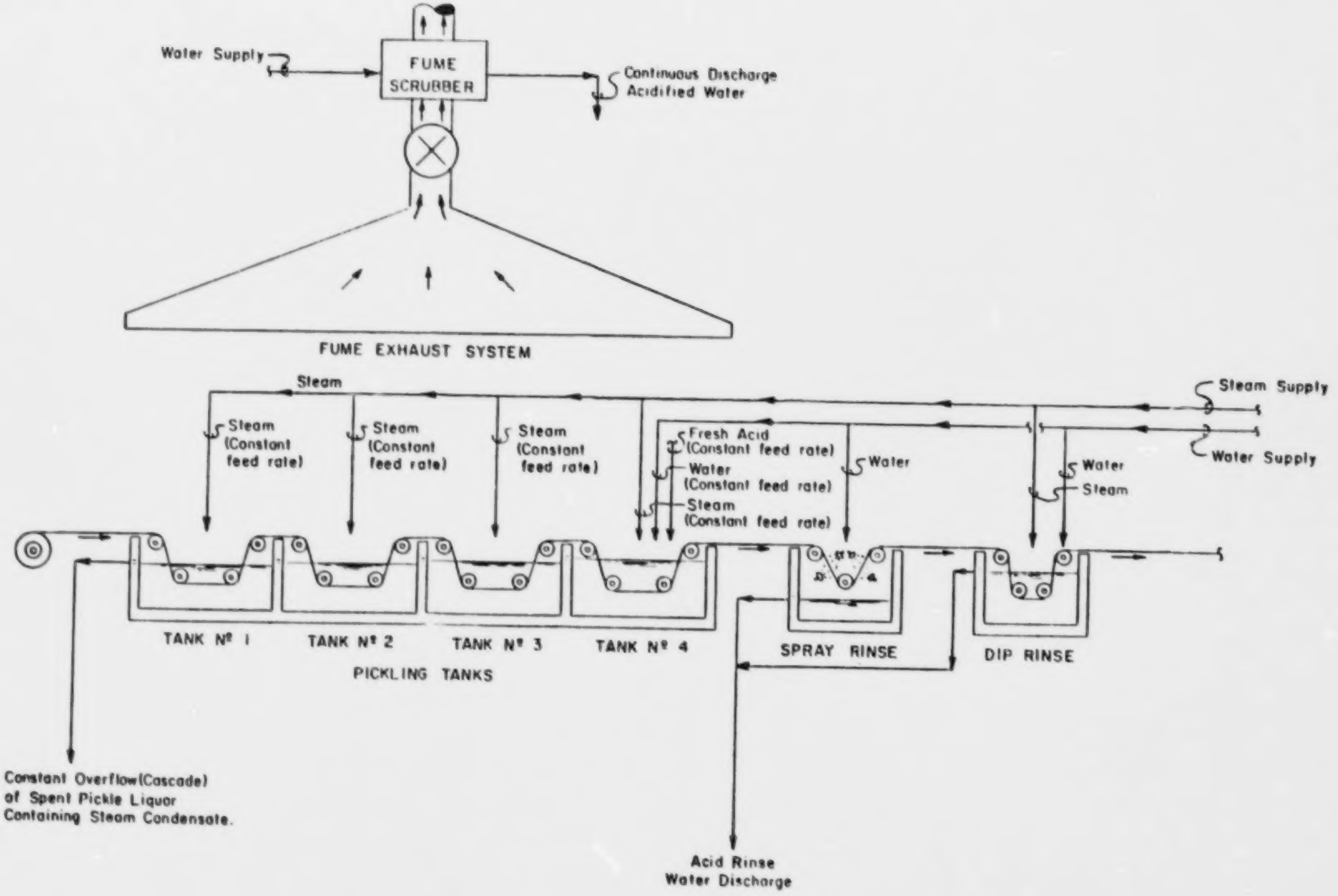

Water Supply
FUME SCRUBBER
Continuous Discharge Acidified Water
FUME EXHAUST SYSTEM
Steam
Steam Supply
Water Supply
Steam (Constant feed rate)
Steam (Constant feed rate)
Steam (Constant feed rate)
Fresh Acid (Constant feed rate)
Water (Constant feed rate)
Steam (Constant feed rate)
Water
Water
Steam
TANK Nº 1
TANK Nº 2
TANK Nº 3
TANK Nº 4
PICKLING TANKS
SPRAY RINSE
DIP RINSE
Constant Overflow (Cascade) of Spent Pickle Liquor Containing Steam Condensate.
Acid Rinse Water Discharge

Figure 2.5-1. Schematic of a continuous strip pickling operation.

Source: Reference 1.

- Hydrochloric acid pickling
  - Strip, sheet, and plate products
  - Rod, wire, and coil products
  - Pipe, tube, and other products
  - Fume scrubbers
  - Absorber vent scrubbers
- Combination acid pickling
  - Strip, sheet, and plate products - batch
  - Strip, sheet, and plate products - continuous
  - Rod, wire, and coil products
  - Bar, billet, and bloom products
  - Pipe, tube, and other products
  - Fume scrubbers

There are 248 sulfuric-acid, 115 hydrochloric-acid, and 152 combination-acid picklers in use.[1] The production breakdown among the three categories is as follows:

Sulfuric acid - 48%
Hydrochloric acid - 44%
Combination - 8%

In this study, only hydrochloric, continuous pickling is considered.

2.5.1 Wastewater Sources and Flow Rates From Acid Pickling

Three waste streams emanate from acid pickling: 1) spent acid solution, 2) rinse water, and 3) fume scrubber water.

Spent Acid Solution--

As more and more steel products are pickled, the strength of the acid goes down and eventually the spent acid has to be discarded. In the case of sulfuric and hydrochloric spent acids, contractor hauling, deep well injection, recovery and regeneration or central treatment are practiced. A summary of the treatment practices for the disposal of the spent pickle wastes in each subdivision is indicated below.[1]

Acid	Contractor hauling	Central treatment	Deep well	Acid recovery	POTW discharge
Sulfuric	44.5%	38.3%	5.2%	2.6%	9.4%
Hydrochloric	53.7%	13.7%	12.6%	8.4%	11.6%
Combination	44.0%	46.0%	0%	0%	10.0%

The flow rates are indicated in Table 2.5-1.

TABLE 2.5-1. AVERAGE PROCESS FLOW VALUES, ACID PICKLING SUBCATEGORY[1]

	Applied spent pickle liquor, gal/ton	Applied rinse, gal/ton
Sulfuric acid		
Strip/sheet/plate	20	160
Rod/wire/coil	20	260
Bar/billet/bloom	20	70
Pipe/tube/other	20	480
Hydrochloric acid		
Strip/sheet/plate	10	270
Rod/wire/coil	10	480
Pipe/tube	10	1010
Combination acid		
Batch-strip/sheet/plate	20	440
Continuous-strip/sheet/plate	20	1480
Rod/wire/coil	20	490
Bar/billet/bloom	20	210
Pipe/tube	20	750

The average applied fume scrubber flow for all acid pickling subdivisions is 135 gpm.

The average applied absorber vent scrubber flow for hydrochloric acid regeneration processes is 100 gpm.

Rinse Water--

The rinsing operation may vary from a one-step dunk or spraying to a more sophisticated, multistage rinsing with cascade rinsing (see Section 3.10). The primary purpose is to remove all traces of contaminants prior to the next step in the processing. Typically, these waters have a low pH ranging from 1 to 2. Rinse water flow averages 400 gpm on continuous lines and 160 gpm in batch systems. Most pickle rinse waters are treated in central treatment systems. They are often combined with cold-rolling wastewaters or waters from alkaline cleaning. Most treatment systems have the following components: neutralization and precipitation of dissolved metals out of the solution by using lime, flocculation, and sedimentation.

Fume Scrubbing Water--

The acid fumes generated in the pickling process must be removed to provide a safe working environment and to minimize corrosion of the equipment and structure. Both water scrubbing and filtration are used to remove acid from the fumes. In the fume scrubbers, the fumes are sprayed with water in spray chambers (low pressure drop) or packed beds. The average applied fume scrubber flow for all acid pickling subdivisions is 135 gpm. The amount of pollutants discharged can be controlled by recycling of this water. The treatment of the scrubber discharge is the same as that used for rinse water.

2.5.2 Pollutant Characterization

Regardless of the type of acid used, spent pickle liquors are highly contaminated with toxic metals. The quality of spent pickle liquor can vary greatly, depending on the age of the solution.

High levels of suspended solids and low pH are the characteristics of acid pickling wastewaters. Limitation of oil and grease are applicable when these waters are processed along with cold-rolling waters. (Treatment of combined pickling rinse water from HCl pickling and cold rolling wastewaters and O&M practices is described in Section 4.5.) The other pollutants present are dissolved iron, fluorides, chromium, and nickel, depending on the materials processed. Several toxic organic compounds were found at concentrations greater than 0.01 mg/liter, but none were considered in the regulations. The effluent limitations depend on the products being pickled.

The daily average BPT limitations for hydrochloric acid pickling in lb/ton are as follows:

	Rod, wire, coil	Strip, sheet, plate	Pipe, tube	Fume scrubber
TSS*	0.286	0.1236	0.596	11.44
O&G**	0.1226	0.07	0.256	4.9
Lead	0.00184	0.0011	0.0038	0.0736
Zinc	0.00123	0.0007	0.0025	0.049
pH	6-9	6-9	6-9	6-9

* Daily maximum = 2.33 x daily average; other daily maximum limitations are three times the 30-day average.

** Limitation only when pickling wastewater treated with cold-rolling wastewater.

BAT limitations are the same as BPT.

Effluent limitations in lb/ton have been promulgated for the absorber vent scrubber wastewater associated with hydrochloric acid regeneration plants:

	BPT	BAT
TSS*	84.0	84.0
O&G**	35.86	35.86
Lead	0.539	0.539
Zinc	0.359	0.359
pH	6-9	6-9

* Daily maximum = 2.33 x daily average; other daily maximum limitations are three times the 30-day average.

** Limitation only when pickling wastewater treated with cold-rolling wastewater.

REFERENCE FOR SECTION 2.5

1. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Industry. Point Source Category. Vol. V. Acid Pickling Subcategory. May 1982.

SECTION 3

TREATMENT COMPONENTS

This section describes the common treatment components in use at steel mills. It also describes a few new technologies; i.e., alkaline chlorination used at some plants for treatment of blast furnace wastewater, cascade rinse and HCl regeneration used at pickling lines. Component operation, pollutants removed, and associated problems are described based on plant visits supplemented by the literature.

Many of the components (e.g., clarifiers, filters) are utilized in treating different process wastewaters (e.g., blast furnace, basic oxygen furnaces). This section describes pollutants removed, governing design parameters, removal capabilities, and types of upsets/problems and their causes. In some cases, O&M practices are highlighted.

3.1 CLARIFIER/THICKENER

3.1.1 Equipment Description/Pollutants Removed

Clarifiers and thickeners are similar physically but they have different applications. A clarifier uses gravity separation to remove from the wastewater stream those suspended solids that have a higher specific gravity than water. Some clarifiers also have a skimmer to remove any oil or other floating material. Figure 3.1-1 shows a typical clarifier.

The feed is introduced into a center well either by a pipe or by an open trough. The center well contains the turbulence generated by the feed entering the clarifier to prevent that turbulence from being transferred into the settling zone of the clarifier. Flocculation clarifiers provide agitation in the center well to promote floc formation. In some clarifiers, this agitation is in the form of separate paddles; in others, the center well is equipped with internal baffles and the entire center well rotates to generate turbulence.

The water flows down through and out of the center well into the settling zone. The cross-sectional area of the settling zone and the feed rate determine how fast the wastewater rises. The rate of rise must be less than the settling velocity of the particles that are being removed. At the top of the clarifiers the water overflows across a weir that runs the full perimeter of the clarifier.

The solids accumulate in the bottom portion of the clarifier, and at steady state operation there is a fairly sharp zone between the sludge and the clarified water. The layer of sludge on the bottom is sometimes called the "sludge blanket." A density gradient exists in the sludge, with the densest sludge at the very bottom.

The clarifier rake serves two functions: 1) it directs the sludge to the clarifier center well for removal, and 2) it produces a gentle agitation that promotes sludge thickening.

If a thickener is used, the sludge from the clarifier is pumped to the thickener, which is similar to the clarifier but has a different function. Its purpose is to thicken the sludge further and then store it. The clarifier sludge is usually dewatered by vacuum filtration.

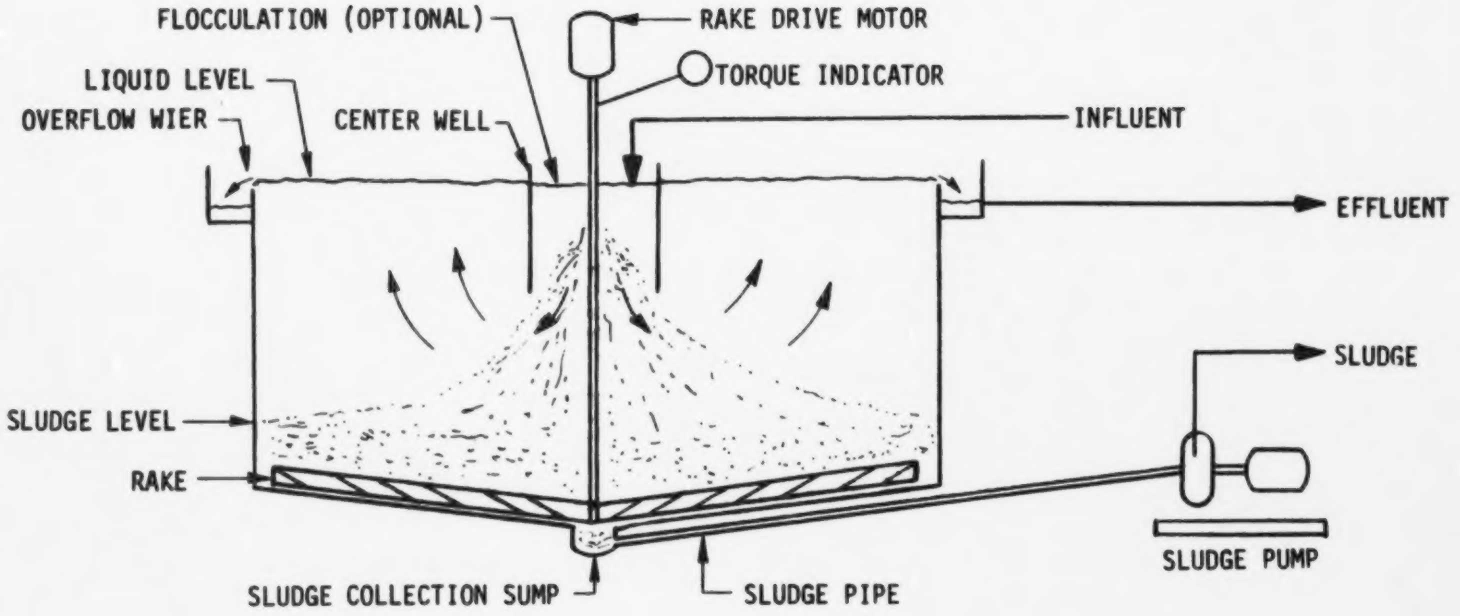

FLOCCULATION (OPTIONAL)
RAKE DRIVE MOTOR
LIQUID LEVEL
TORQUE INDICATOR
OVERFLOW WIER
CENTER WELL
INFLUENT
EFFLUENT
SLUDGE
SLUDGE LEVEL
RAKE
SLUDGE PUMP
SLUDGE COLLECTION SUMP
SLUDGE PIPE

Figure 3.1-1. A typical clarifier cross section.

3.1.2 Governing Design Parameters

The key design parameter of a clarifier is the solids settling rate. This is usually expressed in terms of the rate of liquid rise, which actually determines the clarifier's capacity. This rate must be less than the solids settling rate or solids will be carried out with the water. These rates are typically shown in gallons/minute per square foot, gallons/day per square foot, or inches/minute. The actual rate depends on the individual system, but typical rates are 0.5 to 1.0 in./min or 0.5 to 1.5 gal/min per ft^2.

Sludge density and retention time are also important design variables of the clarifier. If sludge accumulations are not removed rapidly enough, the sludge interface will eventually rise until sludge overflows the clarifier weir.

If the clarifier has a flocculator, the amount of shear generated in the flocculator and the residence time are important design variables. Smaller particles hit one another in the flocculation zone and agglomerate into larger particles that are easier to settle. If the turbulence or residence time in the flocculation zone is excessive, these agglomerated particles may be sheared into smaller particles again. Typical residence time in a flocculation zone is 10 to 20 minutes. Because the volume of the flocculation section is set when the clarifier is constructed, the residence time is dependent on the flow rate to the clarifier. The degree of agitation generally can be adjusted. Both of these are usually design parameters based on results of laboratory settling tests.

The straight-side height of the clarifier in steel applications usually ranges from 12 to 20 feet. Clarifier height is sometimes increased to increase sludge storage volume. The taller units sometimes serve a dual function as clarifier thickeners. High quantities of sludge require a heavy rake mechanism and rake drive system.

If the clarifier contents are pumped to a separate thickening vessel, that vessel is usually considerably smaller than the clarifier. The design and operating parameters of the thickener are similar to those of the clarifier except that a thickener rarely has a flocculation section and the rate of liquid rise is considerably lower. This lower rate results from the thickener being operated in the hindered or compression settling zone whereas the clarifier rate is set by the unhindered settling rate of the particles.

If the thickener operation is well controlled, the thickener overflow can go directly to the clarifier overflow stream; more typically, however, it is returned to the clarifier center well. In fact, in a flocculation clarifier, sludge is sometimes recycled to the center well to promote agglomeration. Recycling can help if the clarifier contents are so low in suspended solids that sufficient collisions do not occur between particles to cause agglomeration.

Since the density of the sludge in a clarifier is usually only slightly greater than that of water, any turbulence can cause the sludge to rise and contaminate the clarifier overflow. Currents induced by inlet flow, outlet flow, wind, or any mechanical failure in the clarifier can cause it to malfunction. The clarifier feed should be introduced to the center well as gently as possible, and the clarifier overflow should be uniform over the entire length of the overflow weir. If multiple clarifiers are used, the flow should be split equally among the clarifiers. A clarifier receiving feed at a high flow rate will not operate as well as one receiving feed at a lower flow rate.

Although the design applications of clarifiers, thickeners, and variations of the two are all slightly different, their names are frequently used interchangeably in industry. The terms in this report are also used interchangeably, particularly to correspond with terminology used by the operators at specific plants.

3.1.3 Removal Capabilities

Removal efficiency of a clarifier and/or thickener can be misleading because of the variation of raw wastewater quality and effluent quality for which the equipment is designed. These treatment components are capable of removing great quantities of solids to effluent levels of 50 ppm of total suspended solids (TSS) or less depending on many factors such as inlet loading, nature of the solids, and whether there is pretreatment (e.g., classifiers), polymer addition, etc. Table 3.1-1 shows actual TSS data on samples taken from eight plants for BOF wastewater treatment. The intention of presenting the data is to provide the reader with a general idea of the performance of clarifiers/thickeners for a steel industry application.

TABLE 3.1-1. PERFORMANCE OF CLARIFIERS/THICKENERS FOR BOF WASTEWATER TREATMENT[1]

Plant	Raw wastewater, mg/liter of TSS	Effluent, mg/liter of TSS	Treatment components
1	418	38	Thickener, polymer
2	359	22	Classifier, thickener, polymer
3	1468	55	Classifier, thickener, clarifier
4	380	47	Thickener, clarifier, polymer
5	3812	81	Classifier, thickener, polymer
6	5375	40	Classifier, thickener, polymer
7	7754	52	Classifier, thickener
8	866	47	Desilter, clarifier

3.1.4 Operating and Maintenance Problems

One of the most common clarifier maintenance problems is a plugged sludge line. Items such as hardhats, tools, and general debris can find their way into the clarifier. When these items sink, the rake moves them into the sump at the bottom of the clarifier and they plug the sludge line. Sludge that becomes too dense also will cause pluggage problems. The best way to minimize this problem is to design the sludge lines so they can be cleaned easily. Some facilities provide a tunnel around the sludge line so the maintenance man will have access to the entire length of the line. Another technique is to install two sludge lines so there is an alternate line if one becomes plugged. Some installations have gone so far as to install a building below the bottom center of the clarifier to house the sludge pumps. At some installations, a wire mesh or some other barrier has been installed across the top or on the sides of the clarifier to prevent large objects from falling in. Whenever the clarifier is emptied for maintenance, the sludge sump should be thoroughly inspected before the unit is put back on stream to ensure that no miscellaneous items (e.g., nuts, bolts) were left there by maintenance personnel.

Debris in the clarifier can also jam the rake. Rake failure also can be caused by mechanical problems such as a section of the rake falling off or the rake getting out of balance and scraping the bottom of the clarifier. If the sludge is not pumped away rapidly enough or its density increases, it can create enough resistance to stop the rake. If the rake stops turning, the sludge just above the discharge well will rathole and the dilute sludge located higher in the clarifier will be taken off instead of the concentrated sludge. The concentrated sludge will then build up in the clarifier, eventually overflow the weir, and create a dirty effluent. Also, the filter may not operate well on dilute sludge.

Most clarifier rake drives are equipped with a torque meter that is set to sound an alarm at a certain level (e.g., 75 percent of full torque) and will automatically shut down at a higher level to prevent the motor from burning out. One facility had a microswitch that recorded each time the rake made a full revolution. This switch was wired to a timer, and if the rotation time of the rake became excessive, it would automatically stop the rake drive and sound an alarm. Another safety feature that is sometimes built in is an automatic rake-lifting device. If the torque becomes excessive, the rake is lifted one or two feet and then slowly returned to its normal position. This lifting action will sometimes free the rake from whatever was restricting its motion. Torque measuring devices are not especially reliable, and one plant considered using motor amps to indicate rake problems. This idea did not work, however, because the mechanical advantage of the motor over the rake was so high (several thousand to one) it was possible for the rake to hit an object and damage itself without stressing the motor.

The condition of the clarifier feed can be checked with a simple settling test consisting of putting a sample of clarifier feed in a graduated cylinder or Imhoff cone and noting the sludge level after a specific time. At one facility the test consisted of filling a 100-ml graduated cylinder and recording the sludge level after 2 minutes of settling. In this case, the clarifier feed was considered satisfactory if the sludge level was between 25 and 30 ml. Although this test does not give an absolute measure of settling rate, it provides a good check for relative settling rates and will detect an upset in the system. If a plant takes this kind of measurement every few hours, a problem in the clarifier feed can sometimes be detected before it leads to a major upset.

The turbidity in the clarifier overflow should be checked frequently. Of the several facilities visited, none had a continuous turbidity measuring device that worked satisfactorily. The instruments they had tried were not reliable. In the plants that have no instrument, the operater should manually pull a sample of clarifier overflow and run a laboratory check on the turbidity. Even with a satisfactory turbidity meter, such manual checks should still be made occasionally to ensure that the instrument is operating properly.

A visual inspection of the clarifier will show the operator that the sludge level is getting near the overflow weir. The operator should also check the uniformity of the effluent flow over the clarifier perimeter weir. If the flow over one portion of the weir is greater than over another portion, the increased velocities can create turbulence.

If all the factors discussed have checked out and the clarifier effluent is dirty, the clarifier may be operating at too high of a feed rate. The operator should check the actual feed rate against the design feed rate. If the feed rate and the area of the clarifier are known, the liquid rise rate can be calculated. There is not always a simple solution to excessive feed rate. This condition is usually the result of an underdesigned treatment plant or of plant expansions after the treatment plant was built. Usually the only solution is to add another clarifier. If the treatment involves multiple clarifiers, it is possible that the flow is not being diverted equally to the clarifiers. In this case, the reason for the uneven flow must be found and corrected.

A more subtle reason for poor clarifier performance can be a change in the feed composition or a problem with the polymer being used. The flocculation and settling performance of the clarifier feed can be checked by use of a standard jar test apparatus (Figure 3.1-2). In this test, a sample of the clarifier feed is placed in a beaker and a paddle is inserted. The proper dosage of polymer is then added, and the paddle is used to mix the contents rapidly for approximately 30 seconds. The paddle speed is then slowed down (to simulate the flocculation zone of the clarifier) and run for about a minute. The paddle is then turned off, and the operator uses a ruler and stopwatch to measure the settling rate. These test parameters are approximate, and the test is more useful if a benchmark test is available that was run during a period of good clarifier operation. This test can be used to compare the polymer actually being used in the clarifier with a fresh batch of polymer made up in the lab to check the quality of the polymer. After the settling rate has been determined, some of the liquid can be siphoned from the jar for a suspended solids analysis. The suspended solids level should approximate the clarifier overflow, but again, this is most useful as a comparative test against a benchmark test.

If the solids being settled in the clarifier come from a scrubber, the problem may be a high level of fines in the water due to furnace operations. These fines make settling more difficult. Sometimes settling can be improved by switching polymers.

Most clarifiers in BOF treatment systems are preceded by a cyclone (primary) separator. If the cyclone malfunctions or is bypassed, it will increase the solids loading on the clarifier.

Settling problems can sometimes be traced back to the polymer. The operator should review the mixing and aging procedures to insure that the

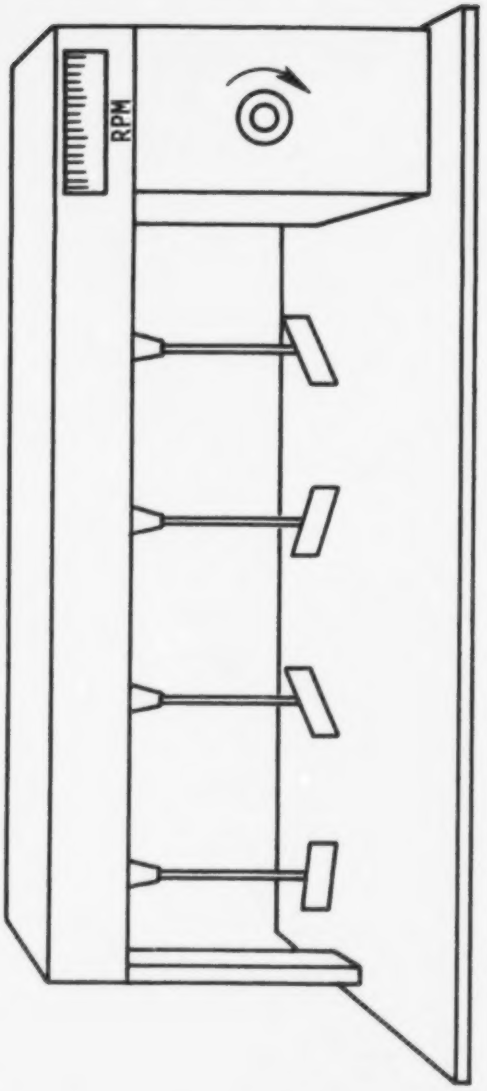


Figure 3.1-2. Jar test unit.

polymer manufacturer's instructions are being followed. If the polymer is hard-piped to the clarifier feed, it may be difficult to ascertain whether it is being added, but this must be verified if the clarifier operation requires polymer. Because of the low flow rate, polymer lines freeze easily in the winter unless freeze-prevention measures are taken. Polymer addition systems are described more completely in Section 3.7.

REFERENCE FOR SECTION 3.1

1. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Volume III. EPA 440/1-82/024. Washington, D.C. 20460.

3.2 RECYCLING

Recycling or recirculation of water back to its source or for another use is not a new practice. For example, steel mills located in areas where water supplies are inadequate to handle plant expansions have practiced partial recycling from clean water discharge areas (e.g., from polishing lagoons), and water from scale pits has been used as flume flushing water. Availability, demand, and cost of water have usually dictated whether recycling was implemented or not.

As cited in Iron and Steel Engineer in August 1972, "The national emphasis on water pollution control as expressed in federal and state legislation during the 1960's has also played an important part in the trend toward water recirculation and reuse."[1] The EPA has been putting considerable emphasis on recycling to reduce wastewater volume and the resultant pollutant loading discharged from the processes.

3.2.1 Obtainable Water Reductions Through Recycling

Recycling is emphasized in the final Development Documents for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, which include recycling in the model treatment systems for 9 of the 12 steel industry categories. The agency estimates that use of the recycling systems can reduce process water discharges by 68.5 percent at the BPT level and by 69 percent at the BAT level.[2] The model recycling rates (BAT) are shown in Table 3.2-1.

TABLE 3.2-1. BAT MODEL RECYCLING RATES[2]

Subcategory	BAT recycling rate,[a] %
Cokemaking (barometric condenser)	95
Sintering	92
Ironmaking	98
Steelmaking	96-100
Vacuum degassing	98
Continuous casting	99
Hot forming	60-77
Acid pickling (fume scrubber)	95-98
Hot coating (fume scrubber)	85

[a] Higher rates of recycling are demonstrated in these and other subcategories. For example, rates of recycle up to 99 percent are common for hot forming operations.

Specific Applications of Recycling--

All of the plants visited implemented recycling in various degrees. It was practiced for all of the studied processes except coke plant biological treatment. Blast furnace recycling is discussed in Section 4.2, BOF recycling in Section 4.3, and hot rolling recycling in Section 4.4. Acid pickling rinse water recycling (i.e., cascading rinse) was practiced at one plant visited, but it was not observed because the blowdown was deepwelled rather than treated in a system. Cascading rinse is discussed in Section 3.10.

Recycling of cleaned water back to process and reuse of water from one treatment system in a different process requiring a lesser water quality (i.e., cascading from one operation to another) is an attractive concept; however, water requirements, wastewater characteristics, and design of tight recycling systems require careful consideration. Most steel mills, and particularly the very old ones, were not designed for the water recycling that is required today.

A carefully designed and implemented tight system or overall plant recycling program can achieve tremendous reductions in makeup water demand compared with once-through water use. For example, more than 10 years ago the Armco-Middletown works achieved a 96 percent reduction in makeup water demand.[1] By the use of 13 separate water recycling systems, the plant was able to operate with about 9000 gal/min of makeup water compared with a total recirculated water volume of more than 200,000 gal/min (see Table 3.2-2).[1]

The use of water recycling has increased since water pollution regulations were initially promulgated, and many plants will implement such systems in conjunction with the installation of additional control equipment to meet current regulations.

3.2.2 Design/Operating Considerations for Recycling Systems

Based on a full-scale trial of a water recycling system on a blast furnace at Republic Steel in Cleveland, a recent paper[3] presented the following concerns and considerations, which are applicable to all tight recycling systems.

TABLE 3.2-2. MILL WATER DISTRIBUTION AND BLOWDOWN[1]

Production area	Makeup, gal/min	Total water used recirculated and once-through, gal/min	Blowdown, gal/min
Coke plant	1,000	10,000	800
Blast furnace	1,000	23,000	770
Open hearth shop	1,100	25,000	290
Basic oxygen shop	300	16,500	50
Vacuum degasser	3,300	3,300	To continuous caster
Continuous caster	(3,300)[a]	15,000	To hot mill
Soaking pits and slab furnaces	500	24,000	To hot mill
Hot rolling mill	(3,200)	70,000	2,500
Picklers	800 (200)	1,000	1,000
Cold rolling mill	700	18,500	500
Annealing furnaces	(300)	300	300
Coating line	75	1,400	30
Total	8,775	208,000	6,240

[a] Parentheses indicate blowdown from another system.

Maintenance of a Tight Recirculation System--

Maintaining a tight system and minimizing blowdown for a hydraulically balanced system require the elimination of extraneous water infiltration from the system.[3] The difficulties arise in trying to identify the sources, measuring their impact on the system (flow, quality, etc.), and eliminating or managing them. Locating sources can take considerable time, depending on their number, the visibility of the piping, and the availability of good, updated blueprints. The detective work may entail trying to find an older employee who can recall something about the original sewer layout. Good updated sewer/piping diagrams are also very useful for a plant spill control and countermeasure plan (SPCC).

Water Chemistry--

Understanding the water chemistry in a recirculation system is very important. In considering such a system, it is important to know the effect of process changes on wastewater characteristics, the compatibility of combined wastewater streams, the chemistry of the makeup water, and the effects of the increased pollutant concentrations on the system. A thorough understanding of the water chemistry of the recycled stream(s) after completion of the number of cycles required for the desired blowdown rate is especially important, and this should be checked during a test trial (preferably full-scale) before a system is fully designed). Dissolved solids buildup that could eventually cause severe plugging problems must be controlled. When the blowdown is large, this may be accomplished through chemical treatment. Republic (Cleveland) decided that such treatment was not adequate for their system, however, so they performed a 2-month study on the use of side-stream softening to control system hardness.[3]

The Langlier and Ryznar Indexes--

Two indexes can be used to predict the scaling tendency in a water system: Langlier's Saturation Index and the Ryznar Stability Index. These indexes, which take into consideration the quantitative values of pH, calcium, total alkalinity, dissolved solids, and temperature, are applicable for waters with a pH between 6.5 and 9.5.

The equations in both of these indexes take into account the pH at which water is in equilibrium with calcium carbonate (the saturation pH, represented as pHs). In a laboratory test, equilibrium is assumed to be reached after standing overnight in contact with pure $CaCO_3$. The pH value measured is the pHs. The pHs can also be determined by the relationship:

$$pHs = 6.301 + pK_2 - pK_s + pCa + pA + S + Ft \text{ (Formula 1)}$$

where p = the negative logarithm (base 10)

K_2 = the second dissociation constant for carbonic acid in water, which equals 4.83×10^{-9}

K_s = the activity product of calcium carbonate in water, which equals 4.69×10^{-11}

Ca = the calcium ion concentration in milliequivalents (meq/liter)

A = total alkalinity as calcium carbonate (meq/liter)

S = a function of the ionic strength (u); this is known as the Larson and Buswell Salinity Correction Factor and has the relationship shown in the sample calculation

Ft = the temperature correction factor; see sample calculation

Langliers' Saturation Index (I_L) is defined as the algebraic difference between the actual measured pH of the water and the calculated pHs at saturation with calcium carbonate.

$$I_L = pH - pHs$$

This index shows qualitatively the tendency for deposition or solution of calcium carbonate. A positive index indicates scaling tendencies, and a negative index indicates corrosive tendencies. A zero index denotes that the system is in equilibrium with calcium carbonate. While very hard water with a positive saturation index will definitely lead to the formation of calcium carbonate scale, softer water with the same positive saturation index may not form any appreciable amount of scale.

In an attempt to secure a quantitative index, Ryznar proposed the stability index:

$$I_R = 2\ pHs - pH$$

An index higher than 7.5 to 8 indicates a corrosive condition. Scale does not tend to form at levels above 6 to 7.5. If the water has an index lower than 6, the tendency is for scale to form and for the possibility of corrosion to lessen.

Although neither index is completely reliable, they provide the engineer with a useful tool for monitoring the system.

The following are sample calculations of indexes:

Sample Calculation

With a given water having the following analysis calculate the Ryznar and Langlier indexes.

pH	8.1
Temperature	102°F (38.9°C)
$CaCO_3$	28 mg/liter
$MgCO_3$	175 mg/liter
Alkalinity	375 mg/liter
Conductivity	1900 umho/cm^3

Ionic strength

The ionic strength (u) is a function of the summation of the product of all dissolved chemical concentrations (c_i) and their charge (z_i). It is formulated as follows:

$$u = 5 \times 10^{-4} \times c_i z_i$$

All of the chemicals dissolved in water contribute to the total ionic strength of a solution. For simplicity of calculation, only the major contributors, magnesium and calcium carbonates, will be considered. The milliequivalent weight of the calcium (Ca) ion in calcium carbonate is 20.04; for magnesium (Mg), it is 12.2. The milliequivalent weight of total alkalinity as calcium carbonate as used later is 50. The charges associated with Ca and Mg are plus 2. The calculation proceeds as follows:

$$u = 5 \times 10^{-4} \times (c_1 z_1 + c_2 z_2)$$

$$u = 0.0005 \times (\frac{28}{20.04}) \times 2 + \frac{175}{12.2} \times 2) = 0.0157$$

Salinity correction factor (S)

$$S = \frac{2.5\ u}{1 + 5.3\ u + 5.5\ u}$$

$$S = \frac{2.5\ (.0157)}{1 + 5.3\ (0.0157) + 5.5\ (0.0157)} = 0.179$$

Temperature correction factor (Ft)

$$Ft = (T-25)\ 0.015$$

$$Ft = (38.9 - 25)\ 0.015 = .21$$

Saturation pH (pHs)

$$pHs = 8.313 + pCa + pA + S + Ft$$

$$pHs = 8.313 - \log_{10}\left(\frac{28}{20.04}\right) - \log_{10}\left(\frac{375}{50}\right) + 0.179 + 0.21$$

$$= 8.702 - \log_{10}(1.387) - \log_{10}(7.5)$$

$$= 8.702 - 0.143 - 0.875 = 7.684 \text{ or } 7.7$$

Ryznar Stability Index

$$I_R = 2pHs - pH = 2\ (7.7) - 8.1 = 7.3$$

Langlier Saturation Index

$$I_L = pH - pHs = 8.1 - 7.7 = 0.4$$

Monitoring and Sampling Requirements--

Determining the success of a trial test on a recirculation system requires a good system for monitoring the performance at regular intervals. Representative samples and proper analyses must be taken and reviewed. Key physical and chemical parameters that Republic (Cleveland) monitored for their system are as follows:[3]

Flows (system, makeup, blowdown)
Caustic feed usage
Temperature
Conductivity
pH
Alkalinity
Calcium hardness
Total hardness
Chloride concentration
Turbidity

Flows were monitored continuously. The water chemistry parameters were measured daily at five strategic locations.[3]

In summary, recirculation of water within a process treatment system or as part of an overall plant recirculation strategy entails consideration of many different things. The ones discussed here (maintenance of system tightness and hydraulic balance, water chemistry, and provisions for adequate monitoring and sampling) are very important. Both good design and effective operating and maintenance practices as described in this study are very important to the success of a recycling system.

REFERENCES FOR SECTION 3.2

1. Thompson, R. J. Water Pollution Control Program. In: Iron and Steel Engineer, August 1972. Armco Steel Corporation, Middletown, Ohio.

2. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category, Volume I. Effluent Guidelines Division, Washington, D.C. EPA 440/1-82/024, May 1982.

3. Wisniewski, L. D., and R. L. Nemeth. Blast Furnace - Recycle System, Side Stream Softening, Summary of Full Scale Trial. Republic Steel Corporation, Cleveland, Ohio. November 1982.

3.3 SCALE PITS/SEDIMENTATION BASINS

3.3.1 Pollutants Removed

Although scale pits (or sedimentation basins) are among the least sophisticated and low-profile treatment technologies, they play a key role in the performance of water treatment plants at hot strip mills.

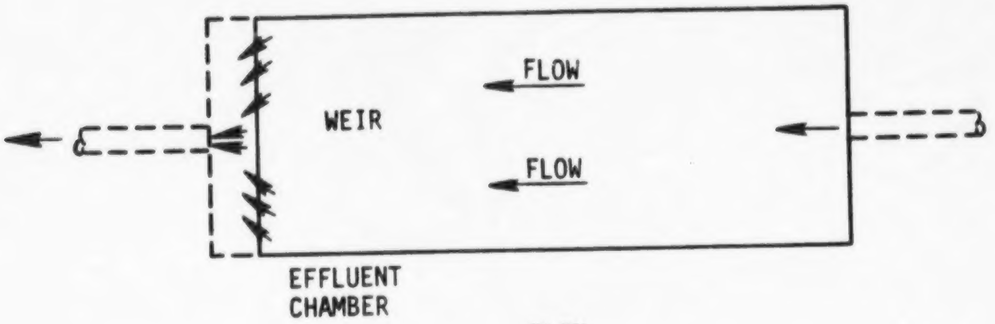
Most of the water supplied to a hot rolling mill is used to descale and cool the strip or bar, to cool the rolls, and to flush the flumes. The scale produced by the rolling of hot steel consists of particles of iron oxide, which become entrained, along with oils and grease, in the discharge water. The volume of water used, the amount and nature of the mill scale, and the oil and grease in the effluent depend on the kind of mill equipment involved, operating procedures, the extent of maintenance, and the housekeeping practices. Water usage ranges from 3,000 to 10,000 gallons for each ton of steel rolled.[1] The amount of mill scale produced varies from 1.5 to 4.0 percent of the tonnage of steel rolled by the mill.[1] The mill scale consists of irregular pieces, flakes, and particles ranging in size from several inches across to particles as small as 0.5 µm.[1] The larger sizes (down to about 100 µm) originate in the reheat furnaces and the roughing mill areas.[1] The very small particles are generated as the steel passes through the high-speed finishing stands.

The main functions performed by the scale pits are:

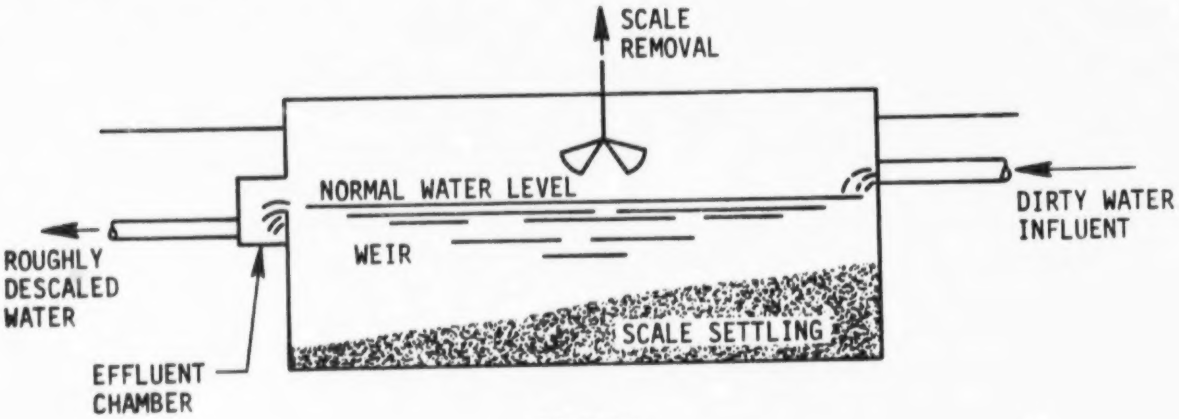
- Sedimentation of heavy, and sometimes light, solids.
- Initial removal of floating oil/grease and scum.
- Equalization of flow and temperature of the mill water.

3.3.2 Description and Governing Design Parameters of Scale Pits

The conventional pit (Figure 3.3-1) is simply a rectangular-shaped basin constructed of concrete and steel. Detention periods in older roughing mill scale pits are generally very short, usually 3 to 10 minutes. At one plant visited, a more modernly-designed 200-ft by 50-ft roughing mill scale pit with a 42-minute design retention time discharged to an outfall. The mill wastewater is discharged into one end of the pit, and the effluent exits from the opposite end. Because of the short detention periods, the conventional pit intercepts only the coarser portion of the incoming scale.


FLOW
WEIR
FLOW
EFFLUENT CHAMBER

PLAN


SCALE REMOVAL
NORMAL WATER LEVEL
DIRTY WATER INFLUENT
ROUGHLY DESCALED WATER
WEIR
SCALE SETTLING
EFFLUENT CHAMBER

SECTION

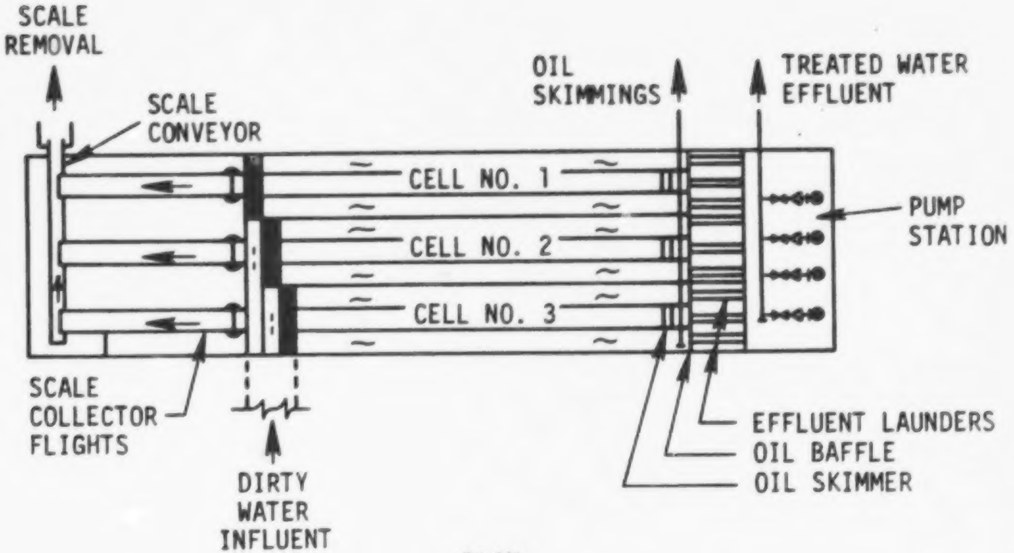
Figure 3.3-1. Conventional-type scale pit.

Reprinted from the August 1970 issue of Iron and Steel Engineer.

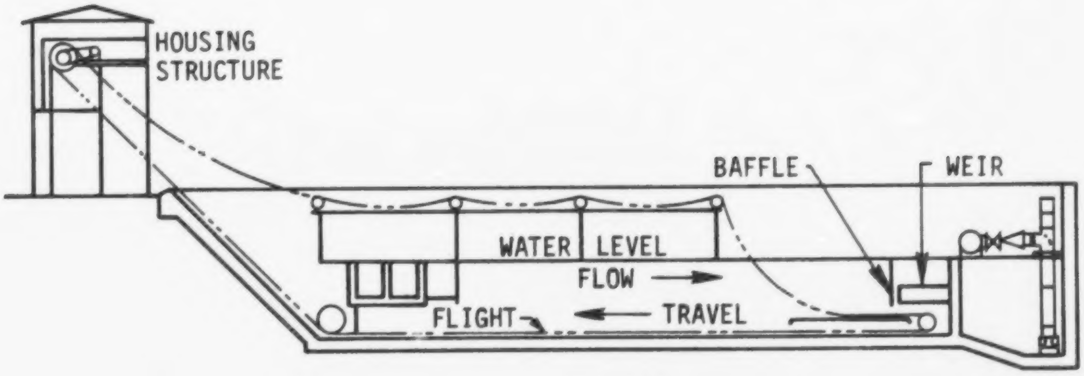
The scale that is collected is usually removed by dredging the pit with a crane-operated bucket, either mobile or stationary. Scale pits can be an effective pretreatment step prior to secondary treatment if properly operated, systematically cleaned, and equipped with oil skimming equipment.

The mechanical scale pit (Figure 3.3-2) consists of two or more shallow rectangular cells adjacent to each other. These cells are 4 or 5 times longer than they are wide.[1] As in the case of conventional pits, the width of a mechanical pit should be less than 20 ft.[2] The width should be kept to a practical minimum because of the difficulty of attaining uniform flow distribution increases with pit depth.[2] Each cell is equipped with a power-operated multi-rake mechanism that drags out the scale collected in the bottom of the tank and carries it up an incline located at the inlet end of the tank. The scale then falls from the rakes onto a cross conveyor belt, which carries it away. Oil skimmers and baffles are located at the outlet end of the pit for oil/grease removal.

An example usage of the mechanical scale pit is at an 80-in. hot strip mill. Each of the pits has three to five cells, each of which is 12 ft wide by 72 ft long with an effective depth of 8 ft above the rakes.[3] The overflow rate is from 8 to 28 gpm/ft^2, depending on the particle size of the material entering the pits.[3] Corresponding retention times range from approximately 2.5 to 5.0 minutes.[3] Oil and grease are removed automatically on an intermittent basis by adjustable skimming pipes. The advantages of mechanical scale pits are as follows: 1) scale is removed continuously (without need of labor to do this task), 2) the quality of the effluent is better than that from conventional pits, and 3) the depth of the installation is less because there is no need for storage space for the deposited scale.[1] The mechanical scale pit, however, also has its drawbacks, which include 1) intense wear and tear of the dragout rakes, chains, and sprockets caused by the mill scale, and 2) the operating limitations caused by malfunctioning rakes. The latter is especially important because if the rakes stop during mill operation, scale quickly settles out and eventually encases the rakes and dragout chains, and the scale must be manually dug out before they can be started up again.


SCALE
REMOVAL
SCALE
CONVEYOR
OIL
SKIMMINGS
TREATED WATER
EFFLUENT
CELL NO. 1
CELL NO. 2
CELL NO. 3
PUMP
STATION
SCALE
COLLECTOR
FLIGHTS
DIRTY
WATER
INFLUENT
EFFLUENT LAUNDERS
OIL BAFFLE
OIL SKIMMER

PLAN


HOUSING
STRUCTURE
BAFFLE
WEIR
WATER LEVEL
FLOW
FLIGHT
TRAVEL

SECTION

Figure 3.3-2. Mechanical-type scale pit.

Reprinted from the August 1970 issue of Iron and Steel Engineer.

3.3.3 Upsets and Problems

The three main functions of scale pits are 1) sedimentation of mill scale, 2) initial removal of oil/grease and skum, and 3) equalization of the flow and temperature of the mill water.

The concentration of scale in the influent to a pit is always fluctuating. At one moment it may be less than 100 mg/liter, and later it may be as high as 2,000 mg/liter. The average usually falls between 200 and 800 mg/liter.[1] Thus, it is not possible to design a single pit that can provide optimum treatment of the different effluents of a mill under varying conditions. The best solution is to provide several different pits, each designed to handle the influent produced by each section of the mill facility (e.g., the 80-in. hot strip mill of the Indiana Harbor Works). The solids removal efficiency of any scale pit is a function of the effective detention time. If the pit fills up with scale, or if the water level is maintained too low, removal efficiency decreases and the solids removal burden on downstream treatment equipment increases. It is not uncommon for plants to experience increased solids loadings out of the pit during scale removal activities; therefore, it is advisable to dredge the pits during mill operation downtimes or to have additional cells or spare pits.

The situation with oily water is more irregular. Under normal operating conditions, oil concentrations in the influent of a scale pit may average from 10 to 30 mg/liter, and for a period of several minutes it can be 100 mg/liter or more.[1] This can be caused by oil spills, line breaks, excessive dripping of lubricants, or the disposal of appreciable quantities of spent oils and greases when the equipment is washed down. The oil skimming arrangements often have difficulty keeping up with oil removal requirements. Apparently, the cost of oils, greases, and hydraulic fluids is not high enough to justify the cost of spill and leakage control at the source. The main effective control strategies for scale pits are good housekeeping and maintained oil skimmers. If practiced, these strategies can result in the interception of a large proportion of the free oils. They are not effective enough to dispense with further downstream treatment, however.

Equalization is an important function at hot strip mills because the water demand is highly variable, changing dramatically each time a slab is rolled. Scale pit capacity must be large enough to dampen these variations while still holding a constant level in the pit. If the level gets too high, the pit may overflow; if too low, the oil skimmers may be less effective (depending on design). This is another reason for incorporating several separate pits and/or spare capacity (i.e., extra pits or individual cells).

Summary of Upsets and Problems--

The following list summarizes some upsets and problems mentioned along with others that can be encountered in scale pits.[1]

- Inlet and outlet conditions that prevent spreading the flow evenly throughout the entire cross section of the pit.
- Turbulence, or eddy currents, formed by the horizontal movement of the waste stream through the pit.
- Surges in the pit caused by sudden changes in the inflow rate.
- Intensive motion within the tank caused by changes in the temperature of the inflow and of the atmosphere, and by outside air currents.
- Adherence of oil to the particles of scale, which slows down or prevents the settling of the finer scale particles.
- Buildup of unremoved scale, which cuts down the detention period and increases the horizontal velocity of the flow through the tank, thereby lowering the quality of the effluent and increasing the possibility of mechanical failure and the need for manual cleaning of the pit.

Suggestions for Improved Performance--

Some suggested ways for improving the performance of existing scale pits are:[1]

- Increase operating flexibility by adding additional pits and/or cells.
- Install scale scalping units that intercept and remove a large portion of the coarser scale upstream of the pit.
- Upgrade the design of the mechanisms and the quality of materials used by the mechanical pits, particularly with regard to chains, sprockets, and drives; the structural strength of the entire mechanism; and the automatic alarms and controls that would be installed. Adequate motor horsepower is also a necessity.
- Provide special facilities for removing the intercepted scale and oil so that the pits are adequately serviced.

- Develop scale removal schedules in conjunction with downstream treatment unit operations to avoid high solids loadings to downstream units during cleaning.

REFERENCES FOR SECTION 3.3

1. Nebousine, R. Present Practice and New Concepts for Handling Effluents From Hot Rolling Mills. Iron and Steel Engineer, August 1970.

2. Hoak, R. D., and H. C. Bramer. Scale Pit Design. Presented at the Chicago Regional Technical Meeting of American Iron and Steel Institute, September 1963.

3. Weymier, R. C. Operating of Wastewater System at Inland's 80-in. Hot Strip Mill. Iron and Steel Engineer, February 1968.

3.4 FILTRATION

3.4.1 Equipment Description

In the iron and steel industry, filtration is used to remove suspended solids from wastewater (polishing filters) and to dewater sludge (dewatering filters). The polishing filters are usually multimedia, sometimes referred to as granular media filters, and they can be operated either by gravity flow or under pressure. Dewatering filters operate either on vacuum or pressure, and several types are available. The use of a centrifuge for dewatering sludge is also discussed in this section.

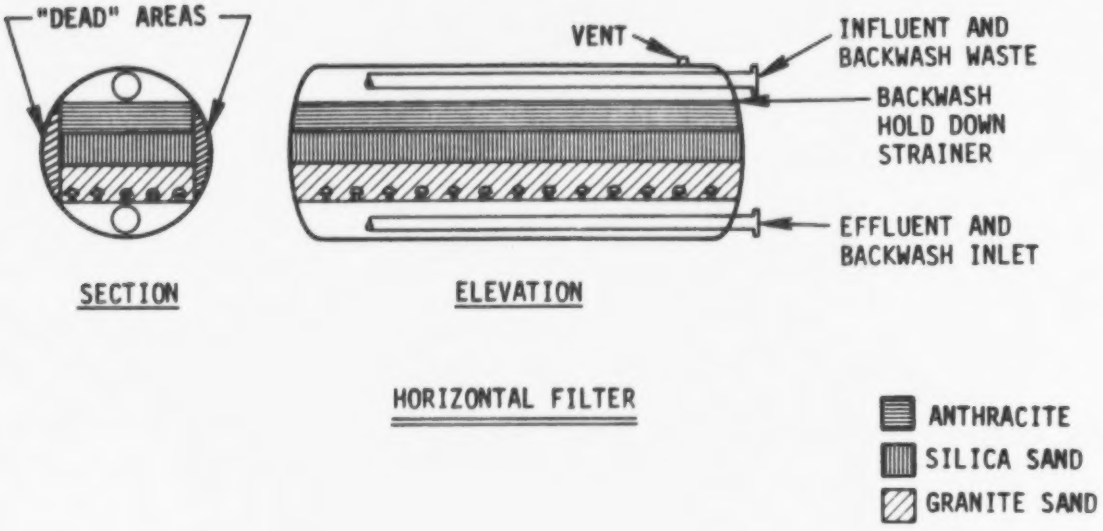
3.4.1.1 Polishing Filters--

Figure 3.4-1 shows the two most common configurations for a multimedia filter. The vertical configuration is used more often than the horizontal filter. The vertical filter is usually either a cylindrical steel tank for pressure operation or a square concrete box for gravity operation. The horizontal tank is normally used for pressure filtration.[1]

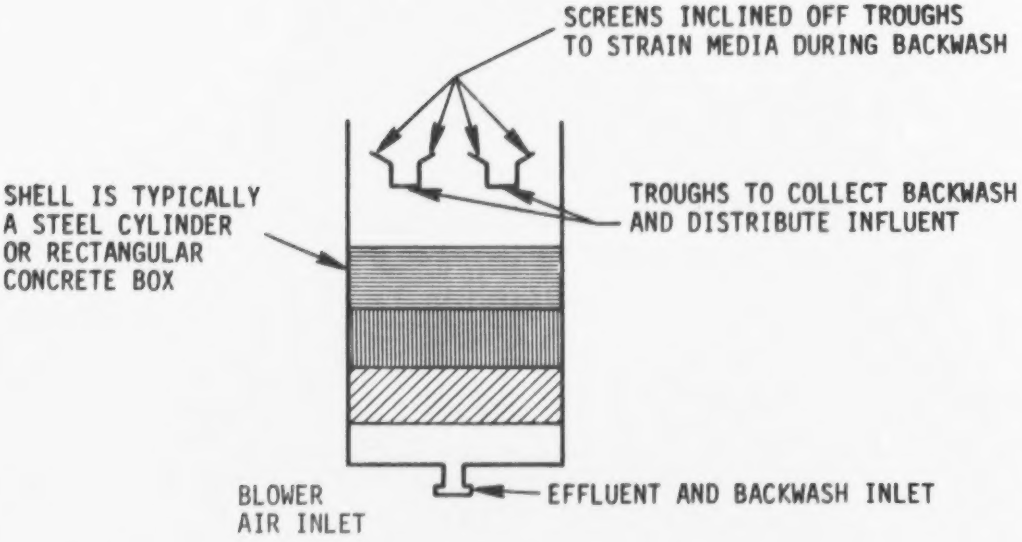
Both filters have similar internals. The water enters the filter media by a distributor plate that helps to spread the water uniformly across the surface of the filter and retains the media. The liquid first contacts the fairly coarse particles, and the bed is so arranged that the liquid passes through finer and finer particles as it progresses through the bed. This gradation of particle sizes allows the larger suspended solids in the liquid to be removed in the coarse portion of the bed and the smaller solids to be removed in the fine portion of the bed. The multimedia bed can remove about 20 times as much material as an ordinary sand filter.[2]

The different particle sizes must have different densities to keep the media stratified. Some common media materials are anthracite coal with a density of 1.35 to 1.75, silica sand with a density of 2.65, and granite sand with a density of about 4.[3]

As liquid flows through the filter, suspended solids become trapped in the media. As the operation proceeds the pressure drop across the filter increases and solids are driven deeper into the filter media. The filtration run must be terminated when the pressure drop becomes excessive or when suspended solids have been driven all the way through the media and the filter effluent is dirty. The filter is taken off line and backwashed to


"DEAD" AREAS
VENT
INFLUENT AND BACKWASH WASTE
BACKWASH HOLD DOWN STRAINER
EFFLUENT AND BACKWASH INLET
SECTION
ELEVATION
▤ ANTHRACITE
▥ SILICA SAND
▨ GRANITE SAND

HORIZONTAL FILTER


SCREENS INCLINED OFF TROUGHS TO STRAIN MEDIA DURING BACKWASH
SHELL IS TYPICALLY A STEEL CYLINDER OR RECTANGULAR CONCRETE BOX
TROUGHS TO COLLECT BACKWASH AND DISTRIBUTE INFLUENT
BLOWER AIR INLET
EFFLUENT AND BACKWASH INLET

VERTICAL FILTER

Figure 3.4-1. Horizontal and vertical multimedia filters.

remove the trapped suspended solids. This involves pumping water through the filter in the reverse direction of filtration and at a high enough rate to fluidize the filter media. To minimize the use of water and create more turbulence, air is usually blown into the filter with the backwash water. This is called air scour. Because of density differences, the media resegregates into layers when the backwash is stopped.

3.4.1.2 Dewatering Filters--

The feed to a polishing filter might be 50 to 200 ppm suspended solids, but the feed to a dewatering filter will be several percent suspended solids. The dewatering filter produces a sludge that must be disposed of or recycled within the steel plant. The most commonly used filter is the rotary drum filter. Disc filters and belt filters are also used where their specific attributes are required. Figure 3.4-2 shows drum and belt filter configurations. Both are vacuum filters.

Drum and disc filters operate in a similar manner. The drum filter consists of a horizontal rotating drum that supports the filter cloth. The bottom portion of the drum is immersed in a tank of sludge. An agitator keeps the sludge in suspension as a vacuum drawn inside the drum sucks water through the filter cloth and causes sludge solids to adhere to the filter cloth. This is called the cake formation zone. As the drum rotates, the cake moves out of the cake formation zone into the drying zone. As the cake is carried around to the top of the drum, a vacuum is maintained underneath the filter cloth to hold the cake and to remove additional water. When the cake passes over the top of the drum, it should no longer have a wet glossy look, but should appear dull and dry. Cracks usually form in the cake as it dries. The belt then leaves the surface of the drum and is directed to the discharge roll. There the belt is forced to make a sharp turn, which usually causes the cake to fall off. Sometimes a blade (known as a scraper blade or doctor blade) runs the length of the discharge roll. This blade, which is adjusted to come very close to the filter cloth, helps remove the cake. The cloth is then washed, either by passing through a trough of water or by being sprayed directly with water. The cloth then returns to the drum and the cycle starts again.

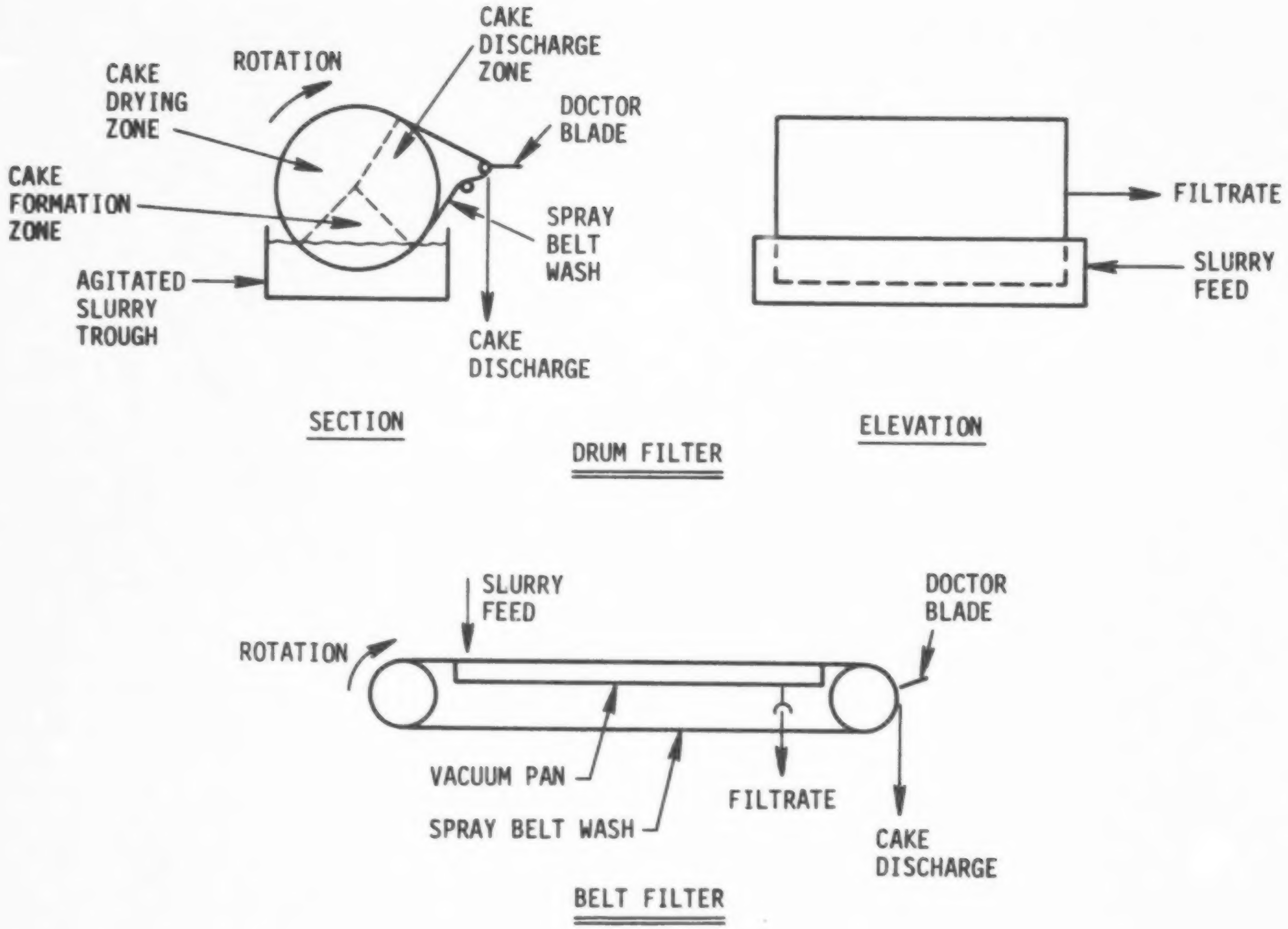

CAKE DRYING ZONE
ROTATION
CAKE DISCHARGE ZONE
DOCTOR BLADE
CAKE FORMATION ZONE
SPRAY BELT WASH
AGITATED SLURRY TROUGH
CAKE DISCHARGE
SECTION
FILTRATE
SLURRY FEED
ELEVATION
DRUM FILTER
SLURRY FEED
DOCTOR BLADE
ROTATION
VACUUM PAN
SPRAY BELT WASH
FILTRATE
CAKE DISCHARGE
BELT FILTER

Figure 3.4-2. Drum and belt filter configurations.

The disc filter, which consists of a row of discs each covered by a filter cloth, is attached to a single central header or hub. As the discs rotate they go through the same cake forming, drying, and discharge cycles that occur in the drum filter. Cake is usually discharged from the disc filter by pressuring the filter and balooning out the cloth. A cake scraper blade is also used. The advantage of a disc filter over a drum filter is that more square feet of filter area can be obtained in the same floor space. This can be an important consideration when retrofitting a filtration system into an existing building.

The belt filter consists of a horizontal belt that passes over vacuum pans. The slurry is poured directly on one end of the belt and the cake discharges at the other end. A belt filter is generally selected when the sludge will not adhere to the bottom of a filter cloth as it must do in the drum and disc filters. At one steel mill, a belt filter is used to process sludge from scale pits because the sludge quickly blinds the filter cloths they had tried. The belt filter used a disposable filter cloth that sits on a roller at the rear of the belt filter. The cloth unrolls, travels across the filter, and is then discharged off the far end along with the cake.

A beltpress filter is a dewatering machine that works on the principle of squeezing sludge between two porous belts as they travel around and through a series of rolls. It is an efficient system that usually has low energy and maintenance requirements. Incoming sludge is usually flocculated with a polymer and conveyed on a pre-dewatering belt where excess water drains away by gravity. The drained solids discharge onto the main press belt which is joined by a second, upper belt, forcing the solids between the two. Both belts are maintained under constant tension. Each press roll has a smaller diameter than the preceding one, causing additional pressure to be exerted on the belts as they move through the process. When the belts again separate, a dry cake is discharged. Discussions with several industry personnel indicate that beltpress filters are probably going to be favored over vacuum filters in the future.

3.4.1.3 Centrifuge--

Figure 3.4-3 shows a horizontal, solid-bowl, desludging centrifuge. The outer solid bowl rotates at a high speed. Centrifugal force drives the solids to the wall of the rotating bowl. A rotating or screw conveyor within the centrifuge turns at a much slower speed and pushes the sludge to

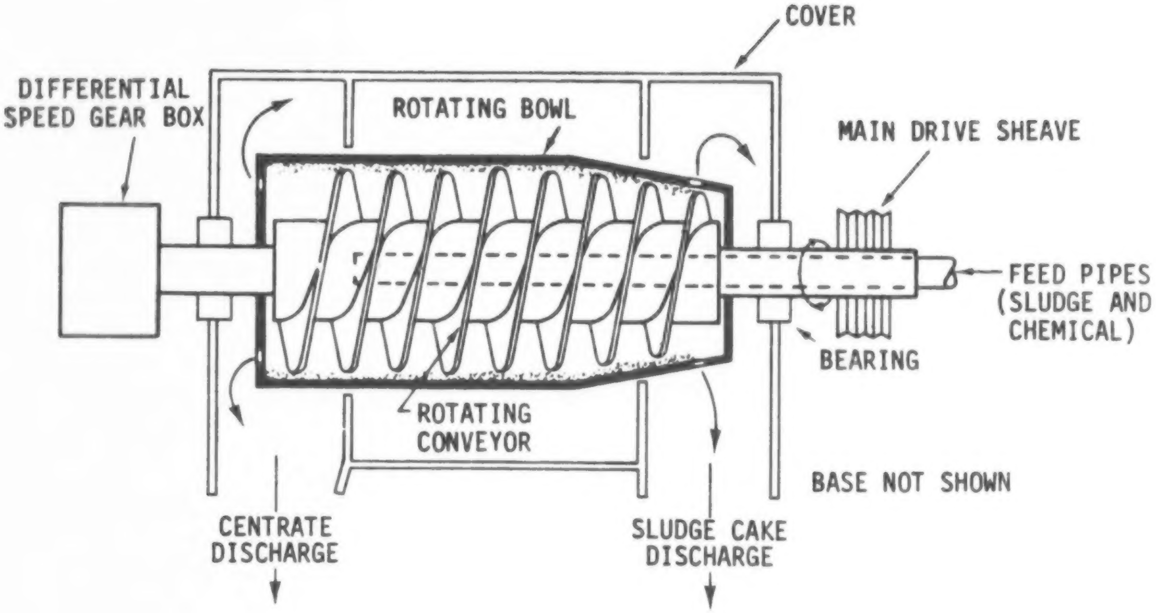

COVER
DIFFERENTIAL SPEED GEAR BOX
ROTATING BOWL
MAIN DRIVE SHEAVE
FEED PIPES (SLUDGE AND CHEMICAL)
BEARING
ROTATING CONVEYOR
BASE NOT SHOWN
CENTRATE DISCHARGE
SLUDGE CAKE DISCHARGE

Figure 3.4-3. Horizontal, solid-bowl centrifuge.[5]

the sludge cake discharge ports. The clean water or liquid discharge ports at the opposite end of the centrifuge are adjusted to maintain the desired liquid level within the bowl. The solids are conveyed along the horizontal portion of the centrifuge to an inclining portion, known as the "beach." The discharge ports at the end of the incline are located above the liquid level in the centrifuge. The liquid level in the centrifuge can be increased or decreased by adjusting the liquid discharge ports. Decreasing the liquid level provides a longer section of the beach in which the sludge is no longer immersed in the liquid and thus produces a drier sludge. The lower liquid level, however, tends to produce a dirtier centrate. These liquid discharge ports are adjusted to produce optimum operation. Increasing the bowl speed increases the centrifugal force and tends to promote clarification, but higher speeds also cause more abrasion within the centrifuge and make it more difficult for the conveyor to scrape the solids up the beach. An increase in the conveyor speed increases turbulence within the bowl and decreases the risk of solids being in the liquid discharge. All these variables must be balanced to produce optimum centrifuge operation.

The centrifuge has the advantage of being much smaller than a filter. Also, some solids do not filter well because they tend to plug the pores in the filter cloth. If the filtration characteristics of the slurry are poor, a centrifuge can be a good solution.

3.4.2 Governing Design Parameters

3.4.2.1 Polishing Filters--

Polishing filters are designed on the basis of surface area. The literature suggests flows of 2 to 6 gpm/ft^2. One of the plants visited reported good operation at 12 gpm/ft^2. In general, the higher flow rates produce a lower quality effluent. One study shows that operation at 32 gpm/ft^2 provided 50 percent suspended solids removal compared with 75 percent removal at 8 gpm/ft^2.[1] The filtration rate and cycle time should be determined by lab testing when a filter is specified for any installation.

Backwashing must be rapid enough to fluidize the bed and float away the material that has been filtered out of the water. If the solids do not tend to adhere to the media or to each other, a water wash of 15 gpm/ft^2 for 6 or 7 minutes is usually sufficient. For solids with higher adhesive forces, an air scour of 3 to 5 scfm/ft^2 together with a water wash rate of 6 to 8 gpm/ft^2 will usually provide good cleaning.[4] The air scour provides turbulence within the bed that releases particles from the media. The washwater is usually obtained from water that was filtered during the first part of the cycle, or is plant service water. As the filtration flow rate is increased, the water wash frequency must be increased. These two parameters must be optimized for good filter operation.

3.4.2.2 Dewatering Filters--

The performance of dewatering filters is very sensitive to the nature of the material being filtered. This can be altered by adding polymers and will usually change at random, as process conditions vary in the plant. Some general observations can be made, however.

Up to a point, filter yield increases as the vacuum is increased. If the sludge is compressible, there is a point at which additional increases in vacuum will produce only a slight increase in yield.

Increasing the drum submergence rate increases the cake formation cycle time and usually results in an increased yield and a thicker but wetter cake. In general, the maximum submergence used on a filter is 25 percent, although higher submergences are possible. The submergence is usually kept between 15 and 25 percent, which gives a long drying time and keeps the cake moisture content at a minimum.[5]

Slowing the drum speed increases the filter cycle time and produces a drier cake, but it decreases the filter's productivity.[6]

The sludge should be handled as gently as possible. Because fines tend to plug pores in the filter cloth and in the filter cake itself, they not only hurt cake production, but they can slowly accumulate in the filter cloth until it becomes unusable and has to be replaced. Only enough agitation should be applied in the filter pan to prevent solids classification and to keep the solids in suspension. Because sludge viscosity varies, optimum control requires variable-speed pan agitation equipment.[5]

3.4.2.3 Centrifuge--

Like the dewatering filter, centrifuge operation must be tailored to the specific sludge being processed. Pool depth affects both clarification and cake dryness. Lowering the pool exposes more drainage deck area, increases the dewatering time, and produces a drier cake. Within limits, increasing pool depth increases clarification by increasing retention time; however, too great a depth prevents a particle from reaching the sludge zone before it is discharged in the effluent. At too shallow a depth, the moving screw conveyor tends to redisperse settled solids.

Conveyor speeds are normally designed or adjusted to minimize turbulence while still providing sufficient conveying capacity. Low speeds also reduce the wear on the conveyor blades when abrasive sludges are handled. Increasing the conveyor speed sometimes produces drier solids because the resulting turbulence washes fines from the cake.

The sludge feed rate is one of the more important variables. It affects both clarity and sludge cake dryness. Higher feed rates in a given bowl means less retention time and a decrease in solids recovery. It also usually results in drier solids in the cake because of the higher loss of fines to the discharge water.

Dewatering filters can usually be sized from laboratory tests. It is always prudent to follow the laboratory test with a pilot-plant-scale test. Centrifuge data, however, do not scale up well from the laboratory. Most major centrifuge manufacturers maintain a complete pilot plant where the material in question can be processed on a full-size centrifuge to determine its operating characteristics.[5]

3.4.3 Operation and Maintenance Problems

Many of the operating and maintenance (O&M) problems and their solutions described here are based on discussions with personnel who operate wastewater treatment systems at steel mills. While the items discussed should be generally applicable to any steel mill water treatment plant, some of the problems and solutions may have resulted from conditions specific to a particular mill. Therefore, engineering judgment must be used in the application of these data to another steel mill wastewater treatment system.

3.4.3.1 Polishing Filters--

One mill visited was conducting studies to improve the operation of its multimedia filters. The plant had been experimenting with a procedure known as declining rate filtration. This type of operating method has been previously investigated by Dr. J. L. Cleasby at Iowa State University.[7] The operation involves beginning the filtration cycle at a high flow rate and then reducing the flow rate for the duration of the run. The result is a reduction in suspended solids in the filter effluent. The theory is that the high initial flow rate gives good solids penetration, which utilizes the total filter bed. The rate declines as the run progresses, which thus reduces the possibility of breakthrough. In constant-rate filtration, the flow is constant throughout the cycle and the solids front progresses steadily through the bed. This front will eventually break through because the rate is not allowed to decline.

Table 3.4-1 shows data collected at a steel mill experimenting with declining rate filtration. This filter was handling scale pit wastewater containing 200 to 250 ppm suspended solids. Note that the declining rate filtration mode produced an effluent containing half the suspended solids of that in the constant rate filtration mode. The value for average suspended solids for each run was determined by taking a sample of the filter effluent after each 25,000 gallons of flow.

TABLE 3.4-1. MULTIMEDIA FILTRATION DATA
COMPARING A DECLINING-RATE AND A CONSTANT-RATE RUN

Variable	Declining rate	Constant rate
Total throughput, gallons	750,000	750,000
Initial filtration rate, gpm/ft^2	18	13.6
Final filtration rate, gpm/ft^2	9	13.6
Average filtration rate, gpm/ft^2	13.6	13.6
Initial S.S.,[a] ppm	6	6
Final S.S., ppm	12	75
Average S.S., ppm	14.2	28.2

[a] S.S. = suspended solids.

The plant was also investigating the effects of a change in flow rate on the suspended solids level of the effluent. They found that any disruption of flow caused an increase in effluent solids level. This phenomenon has also been noted in the literature.[8] An abrupt change in flow rate apparently creates either channeling or turbulence in the filter media, which causes solids to be discharged. Multimedia filters should be fed either by variable speed pumps or by throttling the flow to smooth any flow changes. Using multiple pumps and bringing them on line as needed to maintain the sump level will disrupt the filter.

Another plant reported oil buildup in the filter media, which caused plugging and was difficult to backwash out. One operator said that the oil can occasionally become like a dark thick syrup in the filters and require two or more backwashes to get the pressure drop back to the desired point. Literature reports indicate that a small amount of oil on the particulate matter aids in agglomeration. If the oil content is low enough, it will stay on the solids and be washed out easily.[8] A method for washing out excess oil is to use steam in addition to the air and water when backwashing the filter. One facility successfully solved the problem by using 130 pounds of steam per square foot of filter area in the backwash cycle. The efficient release of the oil affected by the steam was attributed to lowering the viscosity of the oil that adhered to the filter media.[9]

Filters can be set up so that backwash is based on pressure drop, on a time cycle or by level indicators (filter plugging causing liquid level to rise in the filters). At most of the installations visited, the backwash was on a timer and the pressure drop was monitored during the filtration cycle. Some plants had experienced problems with their pressure drop instrumentation being fouled by solids in the water. The actual backwash cycle time and pressure drops experienced in any given multimedia filter are very much a function of that individual filter's design and operation. In general, the pressure drop during the cycle might vary from 6 to 15 ft of water and the backwash time might be anywhere from 3 to 24 hours.

The actual backwashing procedure varies from plant to plant, but the procedure described here is typical. First, the filter must be taken off line and drained, and then a low-rate backwash rinse or prewash is applied with or without air scour. This prewash tends to loosen and separate the compacted sand and particulate matter. The prewash might last from 2 to 5 minutes. Next, a vigorous backwash with water is applied for 5 to 15 minutes. At the end of this wash, the water flow is slowly reduced to allow the media to resegregate. The filter must be equipped with a vent to remove the backwash air at the top of the tank. This prevents excessive backpressure in the line to the backwash surge tank.

Figure 3.4-1 shows a horizontal multimedia filter. This type of filter was being used at one plant to process water that contained about 200 ppm suspended solids from scale pits. The filter was initially designed for 16 gpm/ft^2, but the plant found that it ran best at 8 gpm/ft^2. The designed flow rate was based on the area at the widest point of the cylinder. After startup, the plant discovered that the only active filtration area was between the inlet and outlet distributor plates. The area on either side of the distributor plates was essentially dead space, and solids that accumulated in this area could not be washed out. The accumulated scale would sometimes be dislodged during the backwash cycle and come out in the effluent during the next filtration cycle. The plant also had the problem of media being washed out on the backwash cycle. The distributor plates in this filter were slotted. The bottom distributor plates were covered with a layer of gravel. The plant put screens on the slotted plates at the top of the filter and bubble-cap type strainers on the bottom distributor plates to solve these problems.

The plant also had rectangular sand filters. Two troughs were mounted above the media, and during backwash the filter would fill with water and overflow into the troughs. The air scour induced so much turbulence that the media would wash into the troughs and go out with the backwash water. This problem was solved by mounting screens on the rims of the discharged troughs to screen the outgoing backwash water.

3.4.3.2 Dewatering Filters--

Dewatering filters are normally fed sludge from the bottom of a clarifier or thickener. These filters are usually located in a building some distance from the source of sludge. To prevent the sludge from settling out and plugging feed lines, it is normally recycled from its source up to the dewatering filter and back to the source. Keeping the sludge moving at all times is the best way to prevent plugging. A line tees off from the sludge recirculation line as close to the dewatering filter as possible and goes through a control valve to the filter.

The plants visited used centrifugal sludge pumps with varispeed drives to move the sludge. In many cases they had tried progressive cavity pumps and diaphragm pumps, but the abrasive material would generally destroy the rubber casing of the progressive cavity pump or the check valve in the diaphragm pump. The centrifugal pump should be run at the slowest practical speed to minimize sludge attrition. In some cases, the plants found that the sludge would break up in the recycle mode and would not settle well. One plant was coping with this problem by simply not recycling the sludge and cleaning out the sludge lines as necessary. A good installation will have cleanout taps located strategically along the sludge line.

Two installations surveyed had the same general system for clarifying scale pit water from the rolling mill. These plants pumped the water to multimedia filters. The filter backwash then went to thickeners and from there to dewatering filters. Both plants had tremendous difficulty with the dewatering filter. One plant used a rotating drum vacuum filter, but this filter did not form a good filter cake. The cake would tend to become soupy and blind the filter cloth. When this occurred, the plant discharged the entire filter backwash back to the scale pit while they cleaned the drum filter cloth and tried to get the system operable again. The fines that were sent back to the scale pit increased the load on the multimedia filters so that they required more frequent backwashing. The agitation caused by clam-shelling the scale pits also increased the solids loading to the filters. The plant now clam-shells the scale pit on Sunday, when the mill is down to allow the solids time to settle before startup on Monday.

The other plant used a belt filter for this application. They were never able to find a filter cloth that did not plug quickly, so they used a disposable filter cloth. The cloth was mounted on a roll at the rear of the belt filter and moved across the filter while the cake was added and filtered. At the end of the filter, the cloth and cake discharged together. Because this sludge contained considerable amounts of oil and grease, it was disposed of in a hazardous waste landfill, which was costly. The plant then installed a horizontal-bowl desludging centrifuge in place of the filter. The centrifuge has worked well, and it produces a 10 percent moisture cake as opposed to the 35 to 40 percent moisture cake produced by the filter. Also, the plant no longer has to purchase and dispose of the filter cloth. Because this plant produced about 40 tons of very dry solids a day, the change resulted in a considerable savings in disposal costs. The centrifuge has been a fairly low-maintenance item. The abrasive sludge erodes the discharge ports of the centrifuge, and new steel is welded on to these ports periodically to compensate for that erosion.

Another plant uses disc filters for the sludge in their pickle waste treatment plant. These filters were chosen because of the limited floor space in the filter building. Each disc contains a series of pie-shaped, steel, perforated sectors that are covered by a filter cloth. If the filter cloth on one sector becomes torn, it is relatively easy to replace. The steel sectors are replaced after every two or three cloth replacements because they tend to erode and form a rough surface that in turn will tear a new filter cloth. If a filter cloth develops a hole, the sludge will be vacuumed through that hole at a fairly rapid rate. The sludge is abrasive enough to erode the steel under this condition.

When a doctor blade is used to remove the sludge from a disc or drum filter, the blade must be carefully adjusted. If the blade actually scrapes the filter cloth it will abrade the cloth.

Good level control in the basin of a drum or disc filter is important. If the slurry depth is too low, there is insufficient time to build a good cake. This reduces the rate of solids removal, and thinner cakes are more difficult to break off the cloth. If the level in the filter slurry pan gets too low, it can actually break the vacuum in the filter by allowing air to be drawn in directly through the cloth. A responsive level control is necessary for good filter operation.

If the clarifier or thickener feeding the dewatering filter malfunctions and produces a product that is very low in solids, the resulting cake will be thin and difficult to dry and discharge from the filter cloth.

Most plants consider dewatering filters to be high-maintenance items. The filter cloths are fairly easily torn and the belt on a drum filter can stretch and get out of alignment. Filter cloths usually gradually plug up while the filter is running and require periodic replacement. A dewatering system should have spare filtration capacity or sludge surge capacity so that a filter can be taken off line and repaired without hindering the operation of the rest of the plant. Adequate spare cloths for each filter should be maintained in storage.

The filter cake discharge is usually moved by a screw conveyor. The cake is either dropped directly into a truck bed to be removed for disposal or dropped on the ground and periodically shoveled into a vehicle for disposal. One plant had tried to convey the sludge in tote boxes, but these boxes froze in the winter and could not be emptied.

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3.5 PH CONTROL SYSTEMS

In iron and steel wastewater treatment, pH control is necessary to promote the desired chemical reactions, to maintain a pH range in biological treatment ponds that is not toxic to the bugs, and to produce an effluent pH that is within the permitted limits. In the ammonia stripping columns, the pH is elevated to release ammonia. In another system, the pH of weak pickle liquor solution is raised to produce a ferric hydroxide floc to remove iron and suspended oil from wastewater. In the case of recycle water, including cooling tower water, the pH is normally monitored and adjusted to maintain it in a noncorrosive range.

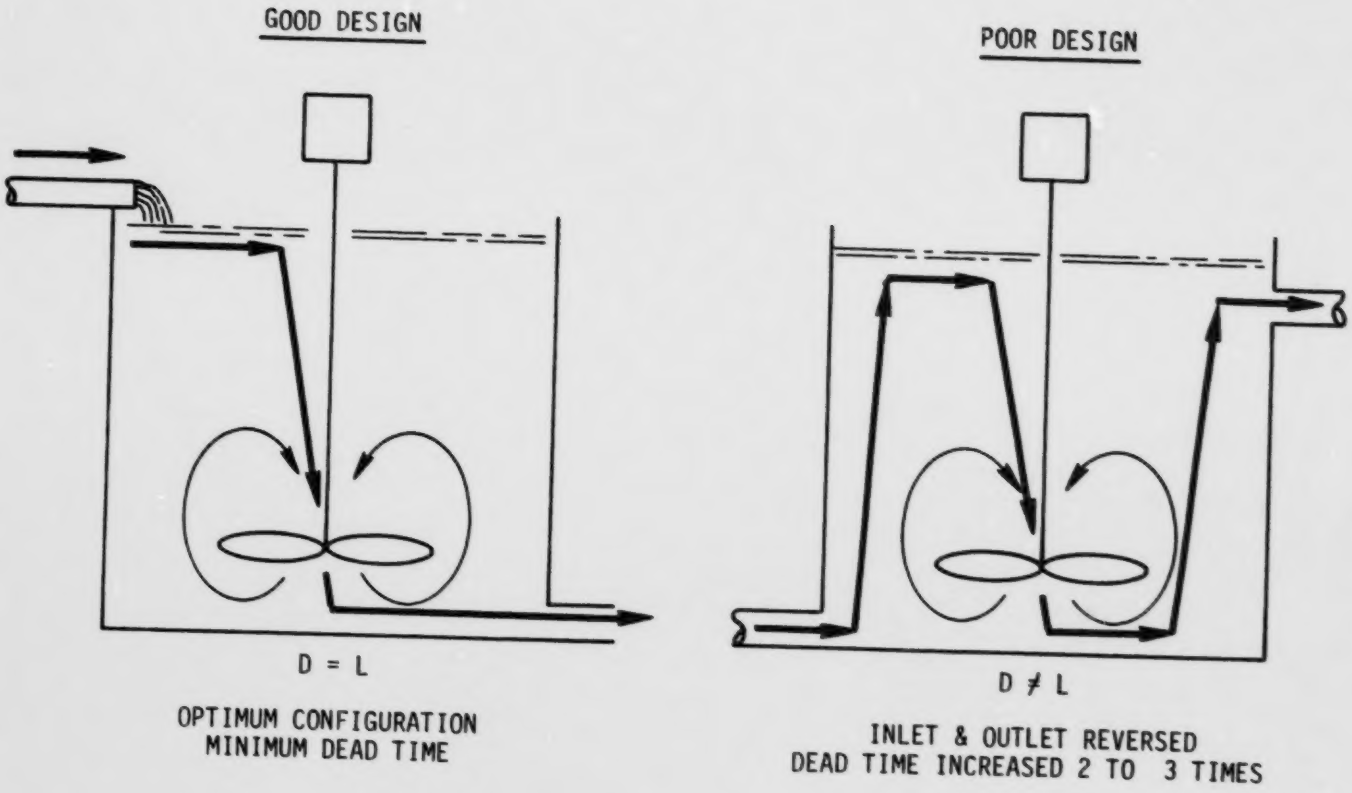
3.5.1 Equipment Description

The major equipment in a pH adjustment system consists of a source of acid or base, an agitated tank, and a control loop consisting of a pH sensor and a control valve.

Ideally, the agitated tank should be cylindrical, and the diameter should equal the liquid level. As a rule of thumb, the retention time should be a minimum of 3 minutes.

The time required to observe a change in effluent pH after the addition of reagent to the pH adjustment tank is referred to as "dead time." This time should be minimized to optimize the responsiveness of the pH adjustment system. In addition to setting the diameter to be equal to the liquid level, the inlet to the mix tank should be at the top of the tank and the discharge should be on the opposite side at the bottom of the tank. These parameters are illustrated in Figure 3.5-1. The tanks also should be baffled to improve mixing.

If rapid pH fluctuations occur in the influent, multistage neutralization is recommended over single-stage neutralization.[2] If too much or too little reagent is added to a single-stage neutralization vessel, these fluctuations are passed directly to the effluent. Thus, the neutralization volume must be very large to reduce these fluctuations. The multistage vessel allows the pH to be fine-tuned. In multistage neutralization, the second-stage vessel should be as much as 5 times larger than the first-stage vessel to avoid amplification of fluctuations. Table 3.5-1 shows the number of tanks recommended to achieve a final pH of 7.0 ± 0.5. In some cases



GOOD DESIGN
D = L
OPTIMUM CONFIGURATION
MINIMUM DEAD TIME
POOR DESIGN
D ≠ L
INLET & OUTLET REVERSED
DEAD TIME INCREASED 2 TO 3 TIMES

Figure 3.5-1. Tank design for pH control.

unagitated (smoothing) tanks are recommended as a final step before release of the treated effluent. The smoothing stage tends to damp out excursions in effluent pH. The presence of buffering chemicals in the wastewater can reduce the need for smoothing capacity, as the buffers themselves damp out pH fluctuations.

TABLE 3.5-1. NUMBER OF TANKS REQUIRED FOR EFFECTIVE pH CONTROL

Maximum possible influent pH range	Agitated tanks +	Unagitated tanks	Total
4-10	1	0	1
2-12	1	1	2
0-14	2	1	3

The control loop consists of a pH controller that senses the pH of the liquid and transmits a signal to the control valve. Based on the liquid pH, the control valve will add the proper amount of reagent to achieve the desired effluent pH. Such systems can be set up as either feedforward or feedback systems. In the feedforward system, influent pH and flow rate are measured and reagent addition is adjusted accordingly. In the feedback system, the measurement is taken after the mix tank.[1]

Because the pH scale is logarithmic, large flucuations in pH require a very wide range of reagent flow rates. For example, to change the pH from 7 to 11 requires 1000° times as much reagent as is necessary to change the pH from 7 to 8. The presence of buffers could make this difference even more dramatic. As a rule of thumb, the best control valves have a maximum turndown ratio of about 50 to 1. Thus, large swings in pH require multiple control valves for good operation. In a multivalve arrangement, the control valves could be sequenced so that only one valve at a time is open. The design should provide for a small overlap in valve ranges so the transition from one valve to the next valve will be as smooth as possible.

The pH controllers can be linear or nonlinear. As the name implies, a linear controller reacts to all pH deviations from the set point by a proportional amount. This type of controller will work if the titration curve of the wastewater is linear in the operating range. The operation of nonlinear controllers is more complex. The controllers must be adjusted so that their output corresponds to the required reagent demand over a range of liquid pH values.

Feedforward controllers are usually more sophisticated than feedback controllers because they must predict reagent requirements based on the influent pH and flow rate. Feedforward controllers can be equipped to provide feedback information to be used to correct the system's performance. With feedback correction, a feedforward system is constantly retuning itself. Feedforward systems are typically used when incoming pH fluctuates so rapidly that a feedback system would be in a constant upset condition.

If the flow is variable, flow rate information must be included in the control system. In one installation, the pH of water being fed to an ammonia still was controlled by a flow-proportional controller with pH bias. In this case, the flow to the ammonia still was monitored and lime was added in an amount directly proportional to the flow rate. The pH of the influent was monitored, and the ratio of lime to feedwater was changed as the pH varied.

3.5.2 Governing Design Parameters

The main design parameters are the nature of the acid or base to be controlled, the precision of control required, and the magnitude of pH and flow rate fluctuations in the influent. Of these, the most important for iron and steel mills is probably the nature of the acid or base to be controlled.

Figure 3.5-2 shows titration curves for three different bases: sodium hydroxide, sodium carbonate, and ammonia.[2] These curves show a comparison of the amount of acid added to neutralize the basic solution with the corresponding decrease in pH. A similar set of figures can be drawn to demonstrate the neutralization of an acidic solution by adding base. These curves are known as titratable acidity curves. The NaOH and NH_3 represent strong bases, whereas the Na_2CO_3 represents a weak base.

The strong bases are the most difficult to control. On the NaOH curve, Zones A and C show little or no change in pH with the addition of acid, whereas Zone B shows an extreme change in pH with the addition of a very small amount of acid. This type of situation is difficult to control because the response to added acid is either extreme (steep slope) or nearly nil (low slope). The ammonia is somewhat easier to control than the sodium hydroxide because the overall pH range of the ammonia solution is smaller

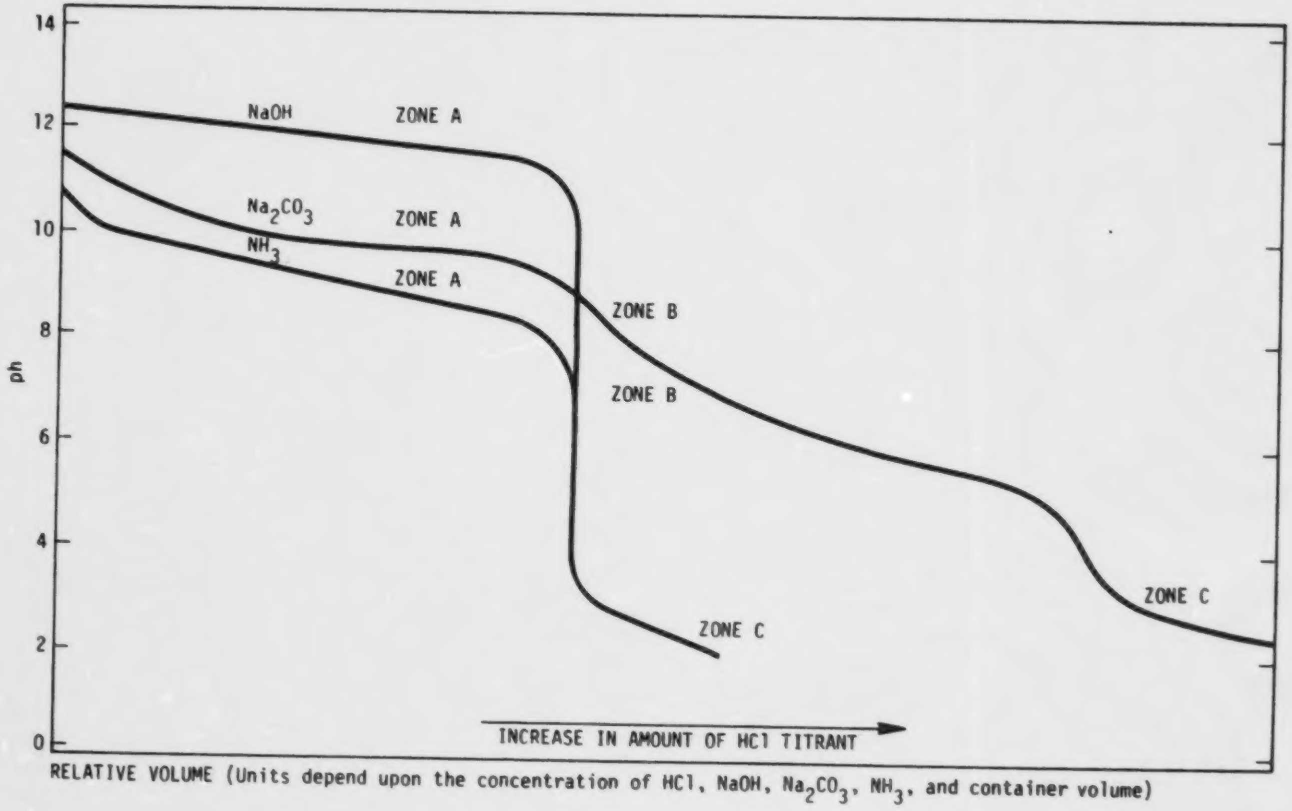


Figure 3.5-2. Titration of NAOH, NH_3CO_3, and Na_2CO_3 by HCl.

and the ammonia titration curve at Zone A is steeper than the sodium hydroxide curve in Zone A.

Of the three solutions illustrated, the sodium carbonate curve represents the zone that is easiest to control, as indicated by its moderate slope in all pH zones. In this case, the addition of small amounts of acid causes moderate changes in pH in all zones at all pH values.

Both ammonia and sodium carbonate act as buffers. A buffered solution tends to resist pH changes. In general, the presence of buffers makes pH control easier, but a buffered solution generally requires a greater quantity of reagent to produce a given change in pH.

Sources of wastewater that have highly variable acid or base loadings are difficult to control. Often the installation of an equalization volume is necessary to balance the acid loading. Equalization volume consists of a tank or basin that accumulates wastewater flows from two or more sources to balance or equalize variations in pH. Spills or intermittent dumps of acids or bases are common examples of industrial sources of abrupt pH changes. One example of this would be an acid spill in the pickling area of a steel mill; another would be a strong acid leak into noncontact cooling water. When such a spill or leak occurs, the pH neutralization system may not have the capacity to control the pH.

3.5.3 Operation and Maintenance Problems and Solutions

The pH electrode assemblies are a frequent cause of malfunction. The proper maintenance of these electrodes is important to both the precision and the accuracy of pH control and monitoring. Three types of electrodes maintenance are required: calibration, cleaning, and replacement. The voltage output of pH electrodes tends to drift when electrodes are left in continuous service. Calibration compensates for this drift. The calibration is accomplished by immersing electrodes in a known pH solution and adjusting the electrical signal to give a reading corresponding to that solution's pH. Many plants calibrate daily.

Solids and oils present in waste streams can hinder the performance of electrodes. Electrodes exposed to these substances must be cleaned periodically to maintain their accuracy. The necessary frequency of cleaning depends on the nature of the waste stream, but daily cleaning is not unusual.

One plant piped service water to the line containing the pH electrodes. Periodically, the process flow is turned off and the service water valve is opened to flush the electrodes with clean water.

When in continuous use, pH electrodes deteriorate over time; therefore, calibration is required more frequently as the electrodes age. If the electrodes are replaced periodically, the need for calibration is less frequent.

Because of its low cost, lime is frequently used for pH control. Although crushed lime can be used directly, slaked lime is more effective. Water and lime are fed to the slaker to create a lime slurry. Lime particle size can be optimized during slaking by controlling the temperature of the slaking water. (One plant reported that 90°C allows the finest particle size to be formed during slaking. This has decreased the loss of unreacted lime through their system by about half.) The slaked lime is then further diluted to the concentration desired for use. Slakers are prone to break down, and enough slaked lime storage should be provided to allow for slaker outages.

The amount of calcium oxide in the lime used must be controlled for consistant operation. A temperature test is sometimes used to quickly evaluate the quality of the lime shipments. A measured amount of water and lime are mixed and the maximum temperature is recorded. The calcium oxide content of the lime can be determined from this value. Plants should be cautious when changing lime vendors because this can result in a change in lime quality.

Plugged equipment is a common problem when lime slurry is used to adjust pH. A control valve in lime slurry service should be checked regularly for signs of pluggage or erosion. By keeping a historical record of electrode failures, control valve failure, line pluggage, and other maintenance problems in a pH system, the plant can set up a preventive maintenance schedule to correct these problems before they occur. Good preventive maintenance is the key to successful pH control.

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3.6 BIOLOGICAL SYSTEMS

3.6.1 Pollutants Removed

The iron and steel industry uses a complete-mix activated sludge process to control biologically reducible pollutants (e.g., phenols) originating from cokemaking operations. The design and operating procedures for these systems are conventional. Single-stage bio-oxidation systems are discussed in this section.

3.6.2 Governing Design Parameters

The design approach and operating characteristics of conventional complete-mix activated sludge systems are well established. Figure 3.6-1 shows a diagram of a single-stage system. The considerations given are those that are rate limiting and thereby establish the size of the reaction basin and sludge settling zone, i.e., the solids settling rate and the BOD, phenol, ammonia-nitrogen, cyanide, thiocyanate, and oil and grease removal rates.

Biologically degradable organics in wastewater can be in solution or in the form of a particulate solid. Only soluble organics can be absorbed and metabolized by the activated sludge microorganism. The rate of metabolism is a function of time, the concentration gradient, and toxicity. Solid degradable organics are removed by adsorption on the activated sludge microorganisms. Adsorption is essentially instantaneous and depends on the effective available surface area. The adsorbed solid is first solubilized through the action of enzymes and then absorbed and metabolized by the activated sludge microorganisms. A relationship between the sludge retention time and biodegradable fraction remaining can be established for any given waste. (This relationship is described later in considerable detail.) Cokemaking wastewaters contain numerous pollutants, as shown in Table 2.1-1. Phenol concentrations up to 500 mg/liter may be metabolized by activated sludge microorganisms, provided an adequate population of phenol tolerant species exists in the mixed liquor volatile suspended solids (MLVSS).[1] In order to reproduce and function properly, the microorganisms must have a source of energy, carbon, and nutrients. Cokemaking wastewaters are typically deficient in the nutrient phosphorus. The addition of phosphoric acid to

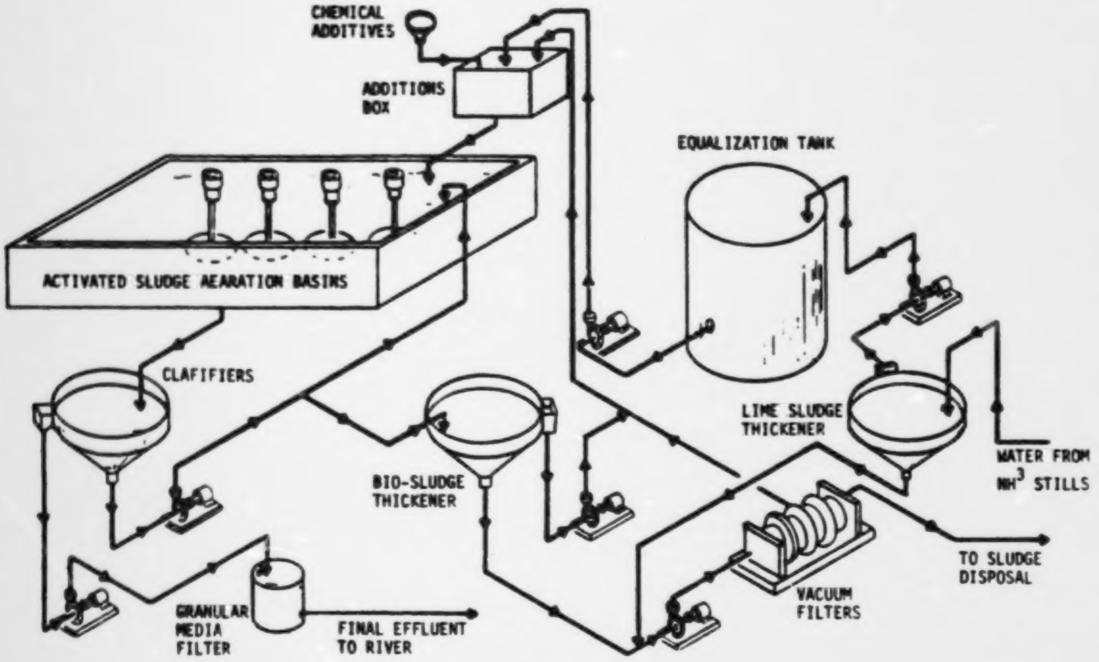
CHEMICAL ADDITIVES
ADDITIONS BOX
EQUALIZATION TANK
ACTIVATED SLUDGE AEARATION BASINS
CLAFIFIERS
LIME SLUDGE THICKENER
WATER FROM NH3 STILLS
BIO-SLUDGE THICKENER
TO SLUDGE DISPOSAL
VACUUM FILTERS
GRANULAR MEDIA FILTER
FINAL EFFLUENT TO RIVER

Figure 3.6-1. Example of a single-stage, complete-mixed, activated sludge system.[2]

the wastewater is necessary to maintain a proper carbon/nutrient ratio for biooxidation. Biological treatment systems designed to treat wastewaters from coking facilities typically operate with 5,000 mg/liter MLVSS and 10,000 mg/liter MLSS and aeration times of 24 to 40 hours. The effluent values of biodegradable pollutants may be calculated by using the following formula:[3]

$$S_e = S_o/[1 + (K_p)(MLVSS)(HRT)]$$

where S_e = effluent pollutant, mg/liter

S_o = influent pollutant, mg/liter

K_p = average pollutant removal rate coefficient for specified temperature, $hour^{-1}$

MLVSS = mixed liquor volatile suuspended solids, mg/liter

HRT = hydraulic retention time, hours

As the equation indicates, the longer it takes the microorganisms to metabolize a given pollutant, the higher the MLVSS that is required or the longer the hydraulic retention time needed to reach the effluent limitations.

Solids (sludge) removal and disposal depend largely on the efficiency of the solid/liquid separation phase of the treatment system. Solids will accumulate in the activated sludge system unless a portion is wasted. This accumulation results from 1) the removal of inert materials and 2) production of cellular material through microorganism synthesis. Because clarifier (sedimentation) efficiency is related to both its overflow rate and the settling velocity of the sludge entering it, the separation system is usually designed for peak flow conditions. The iron and steel industry typically operates the biological treatment system with high levels of MLSS (10,000 mg/liter). Because of this high concentration, the sludge exhibits a zone settling characteristic rather than a discrete particle settling characteristic. The concept of zone settling rate is better understood when expressed as the surface overflow rate because the solids will be lost in the plant effluent if the clarifier overflow rate exceeds the settling rate, i.e.:

$$O_r = V_s \times 7.5 \text{ gal/ft}^3 \times 24 \text{ hours/day}$$

where O_r = surface overflow rate, gal/ft^2/day

V_s = effective settling velocity, ft/hr

Plant operators at the facilities visited have stated that they do not have to waste sludge. This would indicate that most of the solids are going out in the plant effluent and the waste stream contains very little inert material.

3.6.3 System Control Technology

Numerous articles have been written on bio-oxidation treatment systems. Considerable information from one paper, written and presented by Dr. Middleton of Koppers Company, Inc., is paraphrased here because this paper addresses the specific area of concern of this study (i.e., coke plant wastewater treatment).

The described methodology based on solids retention time (SRT) provides a basis for evaluating the operational state of an activated sludge system that has been started up and has progressed to a controllable system.[4]

Table 3.6-1 shows a detailed listing of the control procedure.[4] Figure 3.6-2 presents a daily data sheet for recording the measurements and calculations needed to determine the rate of sludge wasting required to maintain a desired SRT. The procedure also includes calculations for estimating the required rate of phosphorus addition. The soluble effluent phosphorus should be monitored to provide a basis for modifying the calculated value.

On an existing system, the SRT and recycle ratio (r) are usually the only parameters that can be adjusted.[4] Hydraulic retention time (HRT) will vary depending on the inlet flow rate, but design constraints usually prevent its use as a control parameter.

Higher SRT values correspond to less sludge production and, therefore, less sludge wasting. Two of the biological treatment systems visited for this study had SRT's of 20 days and 80 days. The operators reported that there was no "intentional wasting" of sludge. All of the sludge in the clarifier at each system was returned to the aeration basins; any loss of solids occurred only at the clarifier overflow.

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TABLE 3.6-1. ACTIVATED SLUDGE PROCESS SRT CONTROL[4]

1. Select the desired SRT based on operational experience. Usually 20 days is reasonable for BOD, TSS, phenol, oil and grease, and sulfide removal at temperatures ranging from 15° to 20°C.

2. Calculate the weight of total suspended solids (TSS) in the aeration tank daily as:

$$M \text{ in lbs} = (\text{MLTSS})\ (V)\ (8.34)$$

where MLTSS = aeration tank total suspended solids concentration as measured, mg/l; V = aeration tank volume, million gallons; and, 8.34 = conversion factor, mg/l to lb/million gallons.

3. Determine the total weight of TSS to be wasted daily as:

$$\text{lbs to waste per day} = \frac{M}{\text{SRT}}$$

4. Calculate the total weight of TSS lost daily in the clarifier overflow as:

$$L \text{ in lbs lost per day} = (Q)\ (\text{TSS}_e)\ (8.34)$$

where TSS_e = effluent TSS as measured, mg/l (composite sample if possible); Q = effluent daily discharge, million gallons/day

5. Determine the weight of TSS to be intentionally wasted daily as:

$$\text{PI in lbs to intentionally waste per day} = \frac{M}{\text{SRT}} - L$$

6. Determine the volume of recycle sludge to be drawn off daily to achieve this intentional wasting of TSS as:

$$w \text{ in million gallons} = \frac{\text{PI}}{(\text{TSS}_r)(8.34)}$$

where TSS_r = recycle sludge TSS concentration as measured, mg/l.

7. Determine the phosphoric acid addition rate based on the production of volatile suspended solids (MLVSS) as:

$$\text{Phosphoric addition rate in gallons per day (gpd)} = \frac{(\text{MLVSS})(V)(8.34)(\text{P:MLVSS ratio})}{(\text{P content of } H_3PO_4)}$$

where, MLVSS = VSS of aeration tank as measured, mg/l; $\frac{P}{\text{MLVSS}}$ = ratio phosphorus content of VSS, usually 0.024 is reasonable; and, P content of phosphoric acid = as specified, e.g., for 75% H_3PO_4 the P content is 3.13 lb/P/gallon.

Summary of parameters to be measured:

MLTSS:	mixed liquor (aeration tank) total suspended solids, mg/l
TSS_e:	settling tank (clarifier) effluent total suspended solids, mg/l
TSS_r:	recycle sludge total suspended solids, mg/l
MLVSS:	mixed liquor (aeration tank) volatile suspended solids, mg/l

Operator ______________________________ **Date** ______________________________

Aeration Tank Volume

V = ________million gallons

1. Operational SRT ________days

2. Mass TSS in aeration tank (M):

MLTSS = ________mg/l

M = (MLTSS(V)(8.34)

M = ________lbs

3. Mass TSS that must be removed in M ÷ SRT ________lbs/day

4. Mass TSS lost in settling tank effluent (L):

Effluent Daily Discharge

Q = ________million gallons per day

Effluent TSS = ________mg/l

L = (Q)(Effluent TSS)(8.34)

L = ___________lbs/day

5. Mass TSS to intentionally waste (PI):

PI = (M ÷ SRT) − L

PI = ___________lbs/day

6. Waste sludge flow rate (from recycle sludge lines)(w):

Recycle Sludge TSS (TSS_r) ________mg/l

$$w = \frac{PI}{(TSS_r)(8.34)} \times 1{,}000{,}000$$

w = ___________gpd

$\frac{P}{MLVSS}$ Ratio = ________

P Content of Phosphoric Acid = ________lbs/gal

7. Phosphoric acid addition required:

MLVSS = ____________mg/l

MLVSS Production = (MLVSS)(V)(8.34) ÷ SRT

MLVSS Production = ____________lbs/day

lb P required = (MLVSS Production) ($\frac{P}{MLVSS}$ Ratio)

lb P required = ______________lb/day

Phosphoric Acid addition rate = (lb P required) ÷ (P content)

Phosphoric Acid addition rate = ____________gpd

Figure 3.6-2. Daily Data Sheet.[4]

Operation at longer SRT values allows a higher biomass concentration in the system (Figure 3.6-3), which provides greater stability to changing loading conditions.[4] Longer sludge retention times also lead to improved effluent quality for pollutants affected by biological oxidation.[4] When operating for a given wastewater loading, two factors will limit the maximum SRT value that can be achieved: settling tank capacity and aerator capacity. Various other curves, based on developed equations and measured data from a byproduct coke plant producing foundry coke, are presented in Reference 4. Two graphs included in this discussion relate to the settling tank area and aerator capacity. Figure 3.6-4 shows the relationship of required final settling tank area vs. mixed-liquor total suspended solids (MLTSS). Figure 3.6-5 shows aeration tank dissolved oxygen vs. solids retention time.

By developing one's own graphs based on specific system and conditions, one can estimate the maximum solids retention time and minimum recycle rate for a specific system. By making incremental adjustments of the actual SRT and r values to the new estimated values and measuring the key concentrations mentioned, one should be able to approach an optimum operational state. The reader is referred to Reference 4 for further detail.

3.6.4 Types of Upsets, and Problems and Their Causes

Because biological treatment systems operate by the functioning of living organisms that require a stable diet and environment, any abrupt changes in conditions outside the bugs' tolerable limits can partially or totally destroy a bug population and thereby destroy the treatment system. Some upsets are caused by poor performance of the ammonia still; swings in basin flow, pH, and temperature; interruption in nutrient addition; and inadvertent changes in sludge wasting and recycle rates made by an operator who does not understand the effects of such changes.

Illustrations of specific upsets and their effects that are provided here are based on a paper describing biological treatment of coke plant waste by use of an integral clarification concept.[5] The authors' reactions to the treatment system are very positive, and the few examples of upsets they describe do not discredit the system, but merely show how upsets can affect a system.

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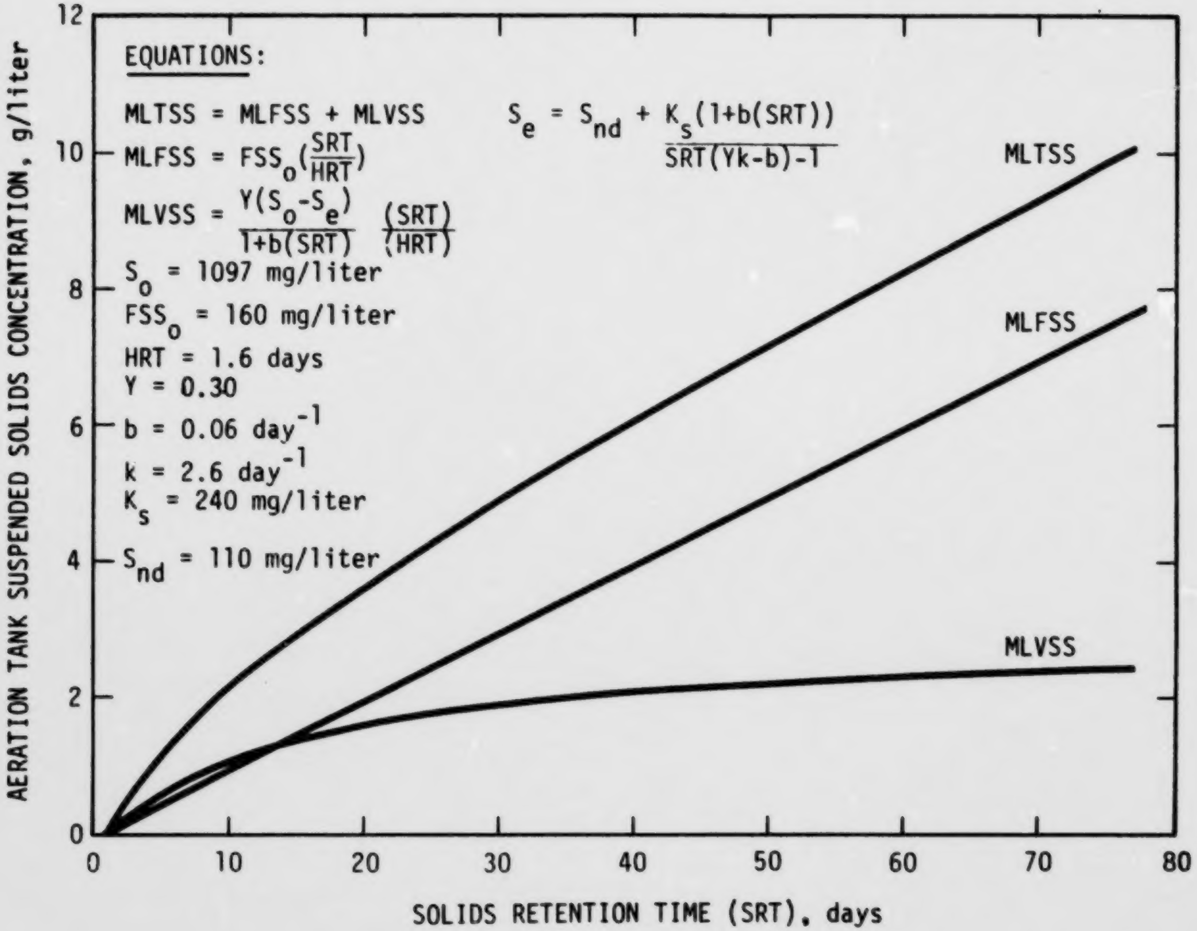


Figure 3.6-3. Relationship of MLTSS, MLFSS, AND MLVSS to solids retention time.[4]

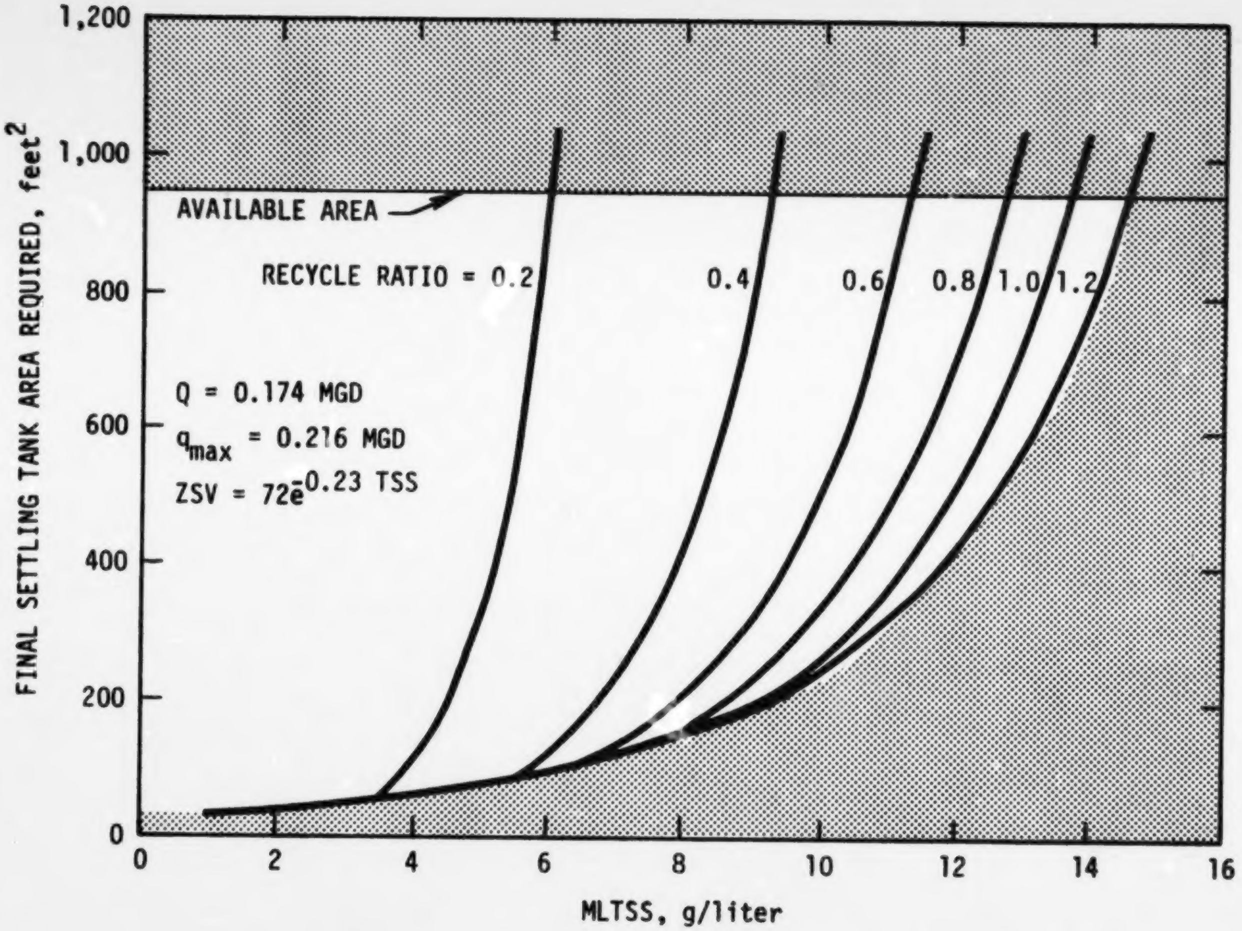
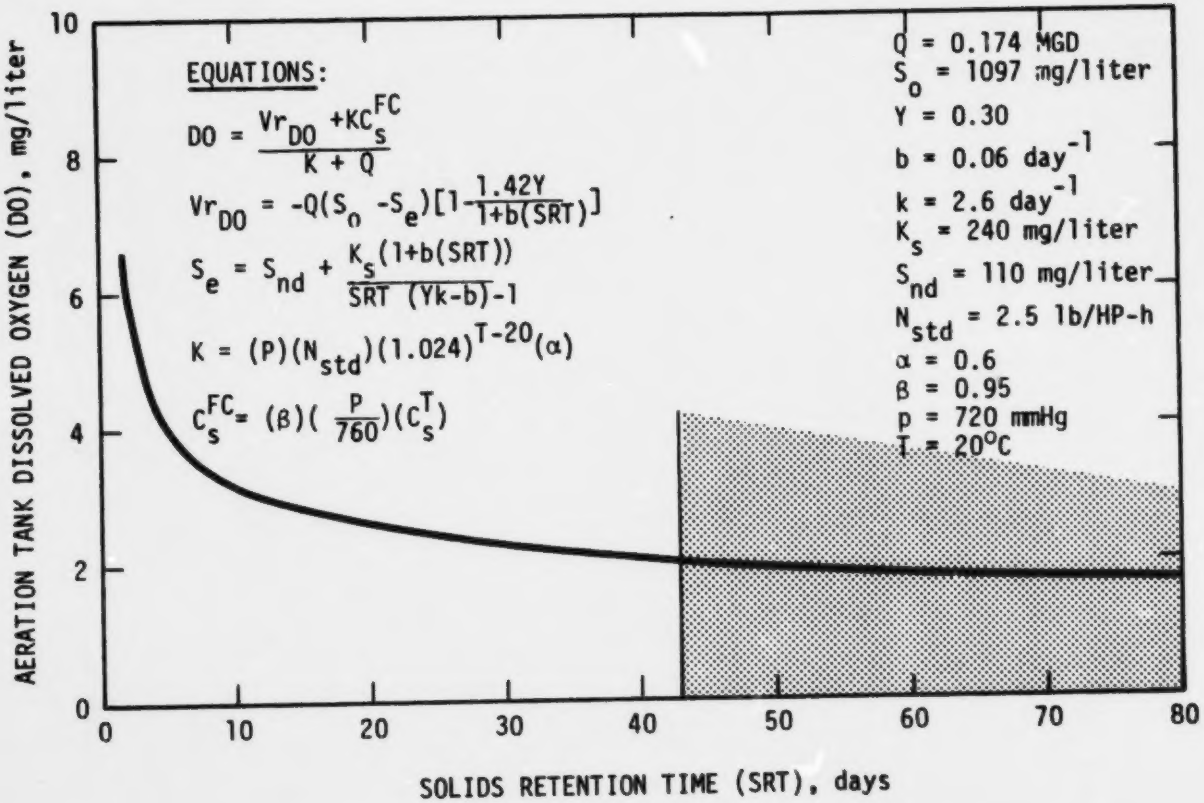


Figure 3.6-4. Relationship of required final settling tank area to MLTSS and recycle ratio (r).[4]



$$DO = \frac{Vr_{DO} + KC_s^{FC}}{K + Q}$$

$$Vr_{DO} = -Q(S_o - S_e)[1 - \frac{1.42Y}{1+b(SRT)}]$$

$$S_e = S_{nd} + \frac{K_s(1+b(SRT))}{SRT\ (Yk-b)-1}$$

$$K = (P)(N_{std})(1.024)^{T-20}(\alpha)$$

$$C_s^{FC} = (\beta)(\frac{P}{760})(C_s^T)$$

$Q = 0.174$ MGD
$S_o = 1097$ mg/liter
$Y = 0.30$
$b = 0.06$ day^{-1}
$k = 2.6$ day^{-1}
$K_s = 240$ mg/liter
$S_{nd} = 110$ mg/liter
$N_{std} = 2.5$ lb/HP-h
$\alpha = 0.6$
$\beta = 0.95$
$p = 720$ mmHg
$T = 20^oC$

Figure 3.6-5. Relationship of aeration tank dissolved oxygen concentration to solids retention time.[4]

Ammonia Still Performance--

Figure 3.6-6 shows a drastic increase in ammonia loading at a biological system as the result of the last free tray of the ammonia still becoming plugged with tar and pitch. (This particular plant uses sodium hydroxide in the still, but plants using lime frequently get plugged trays because of scaling.) At this plant, a well-designed extended aeration system, designed for ammonia removal, was able to handle the shock loading fairly well. The effluent concentration increased several times above the normal, but the ammonia removal efficiency of the system remained very high. The figure is intended to show that ammonia still problems such as tray pluggage can produce significant changes to the basin influent. A loss in steam flow to the still would produce similar effects. These upsets would be much more noticeable on biological systems not designed for ammonia removal (e.g., most single-stage systems).

Basin Flow--

A higher-than-desired flow will affect hydraulic retention time, which can affect pollutant removal capability. A more realistic example of a basin flow problem is a temporarily high flow that can disturb solids settling in the settling tank or disturb the sludge blanket (if it is high enough). An example of the latter is shown in Figure 3.6-7. This condition caused a carryover of solids from the clarifier effluent.

Nutrient Addition--

Loss of flow of nutrient (i.e., phosphoric acid) to a biological system can cause a rapid increase in biologically reducible pollutants. Figure 3.6-8 illustrates an incident when phosphate concentrations in a system were inadvertently depleted. The figure shows the effect on thiocyanate, as the plant used this parameter to determine the relative health of the system.[5] (This parameter was also used at two of the plants visited on this study.)

Effect of Problems and Upsets--

Conditions that cause great increases in pollutant concentrations to a biological system may or may not adversely affect the performance of the system. The effect of the problems depends on many factors, e.g., system design, biomass concentration, and ability of the operators to divert flow to an emergency tank or lagoon. The latter depends on quickness of communication from the byproducts plant and whether an emergency backup is available.

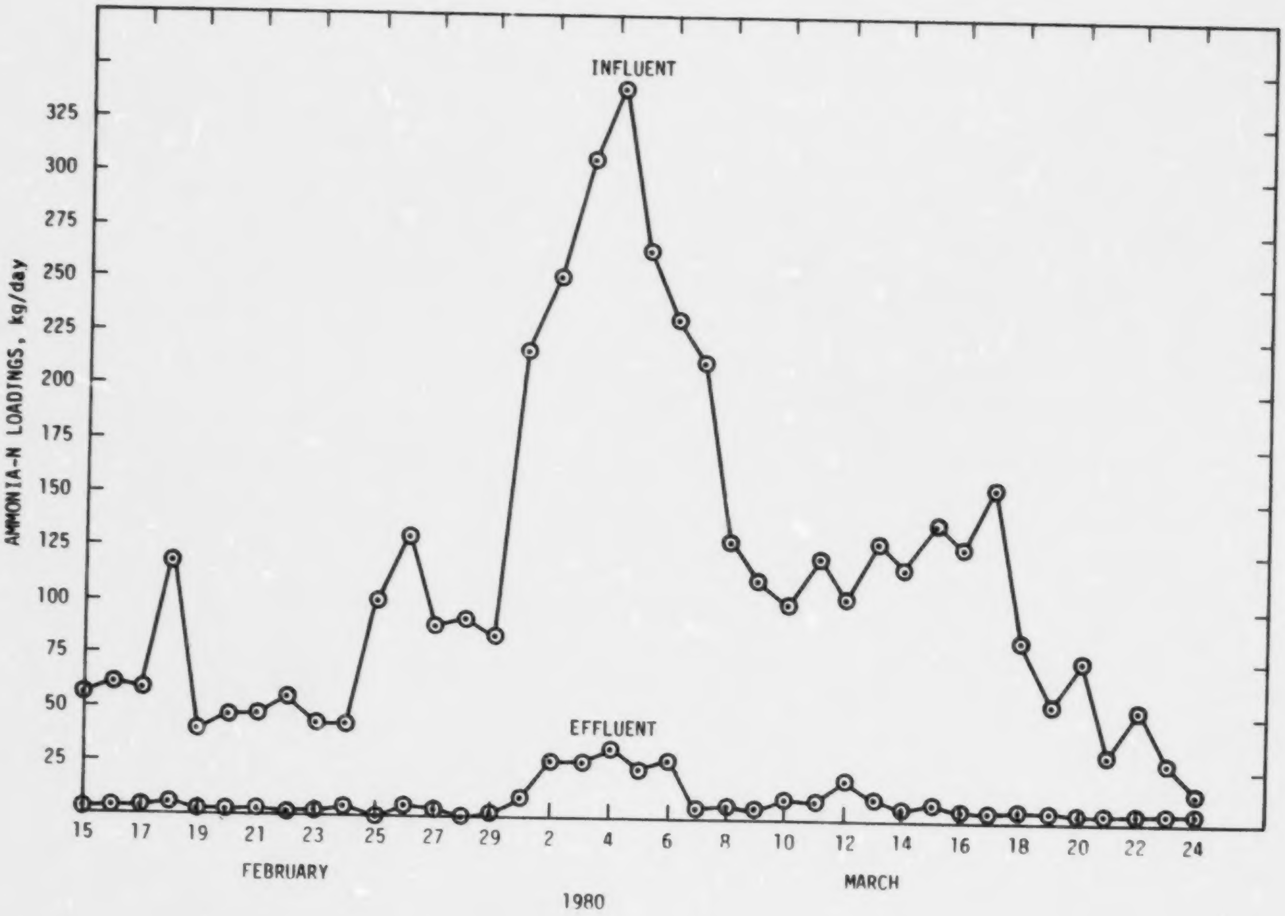


Figure 3.6-6. Ammonia upset = influent and effluent total daily loadings.[5]

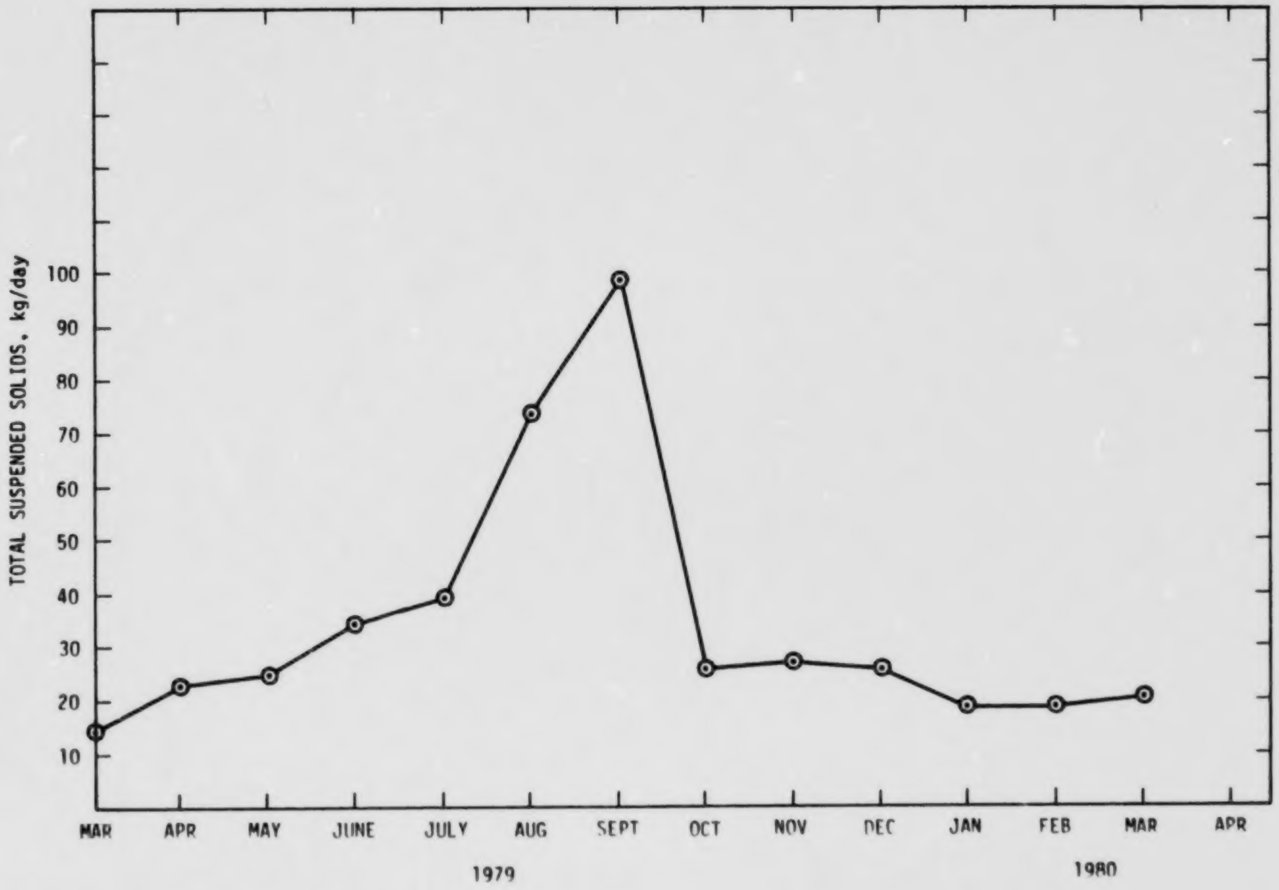


Figure 3.6-7. Effluent total suspended solids average daily discharge.[5]

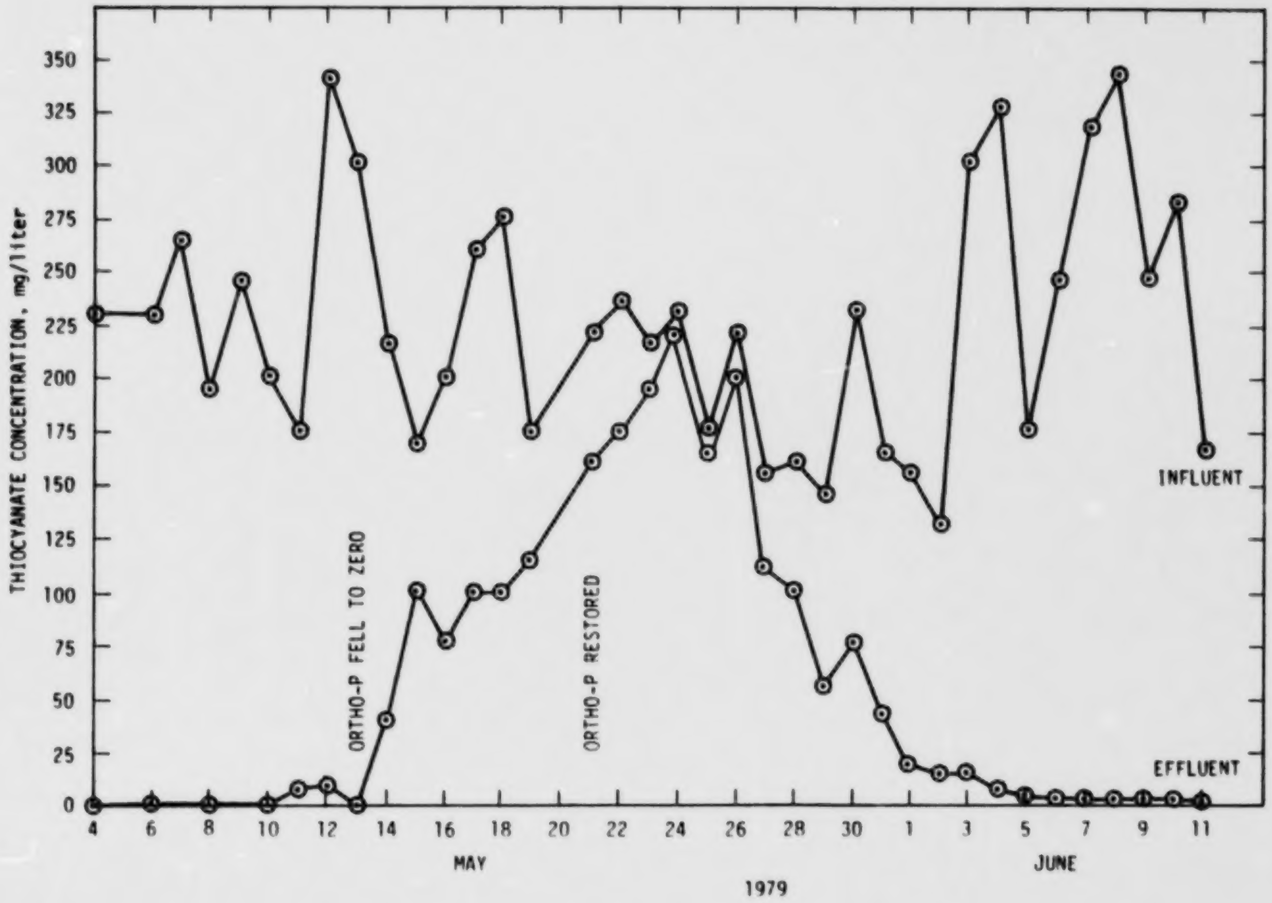


Figure 3.6-8. Upset conditions due to lack of phosphorus nutrient as indicated by thiocyanate[5]

Some conditions causing increased influent loading have little effect on system performance, as illustrated in Figure 3.6-9; whereas others can cause a massive bug kill and hinder the performance of a bio-oxidation system for weeks, until the bug population stabilizes. This long-term effect is illustrated by Figure 3.6-10, which shows MLTSS (indicative of MLVSS) vs. time. (The actual figure is based on system startup. This example is based on a "restart" of the bug population after a massive kill.)

Effective O&M practices pertaining to biological treatment systems are discussed in Section 4.1.

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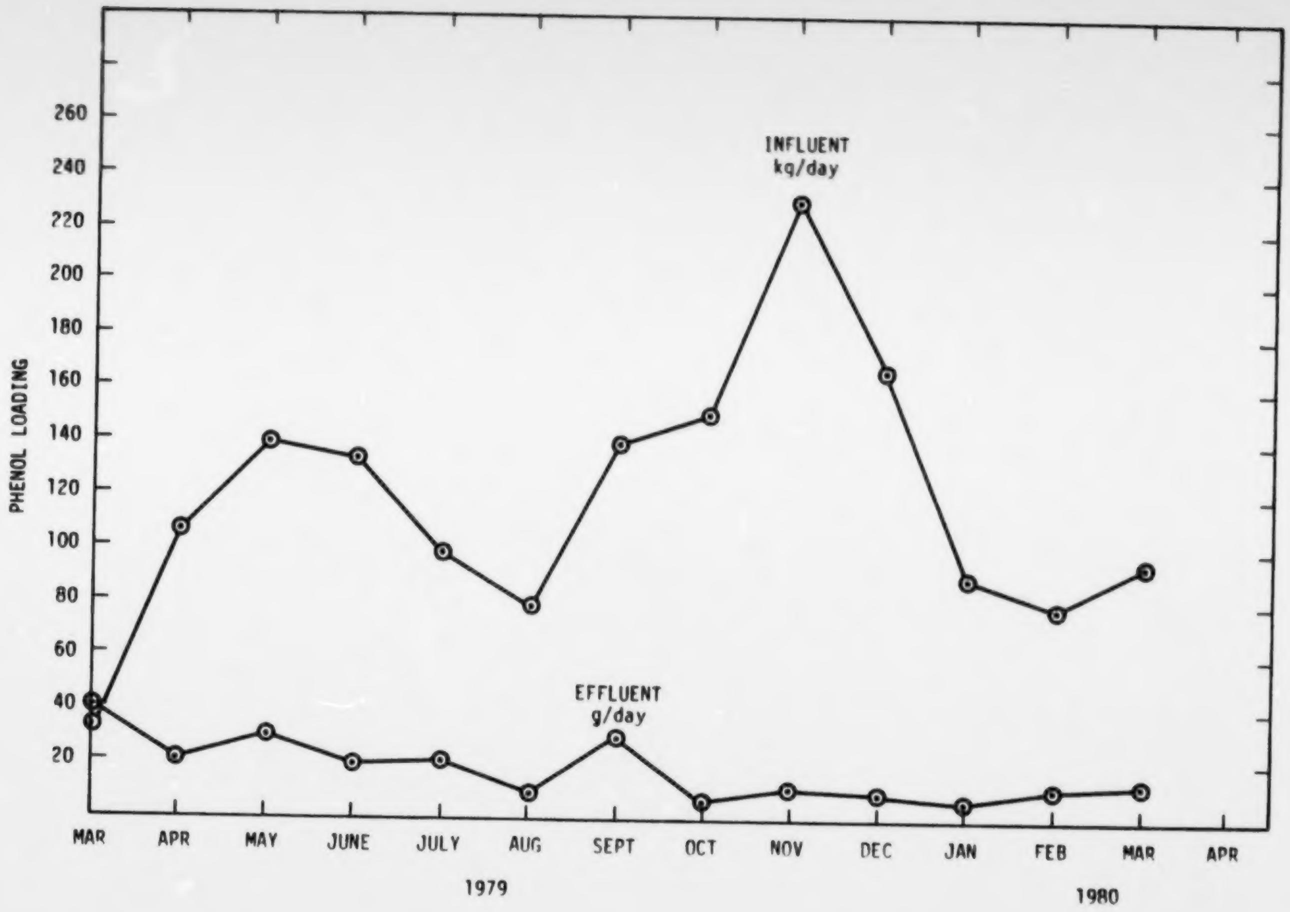

Figure 3.6-9. Phenols: influent and effluent average daily loadings.[5]

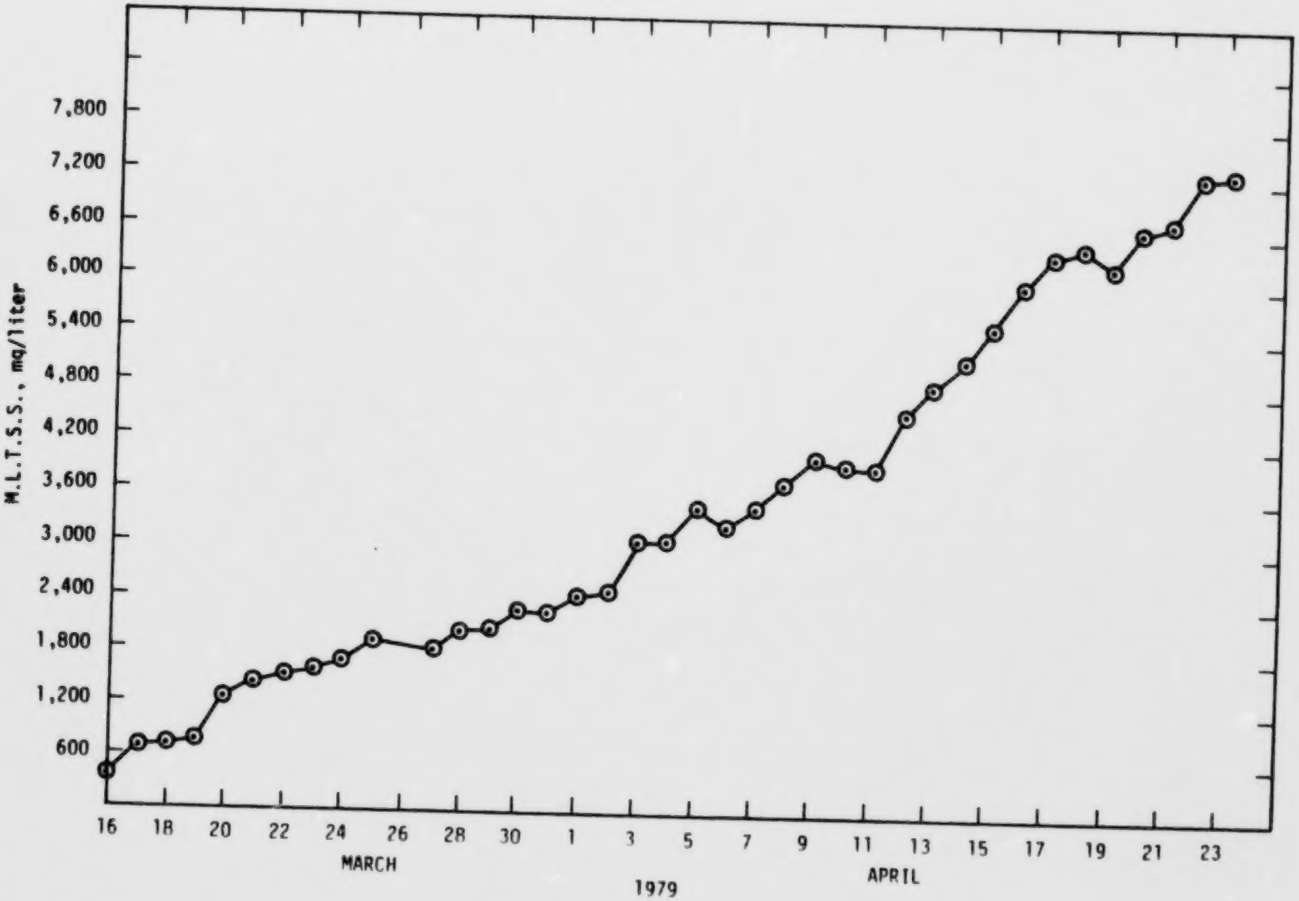

Figure 3.6-10. Total suspended solids in mixed liquor during startup.[5]

3.7 CHEMICAL ADDITION SYSTEMS

Iron and steel wastewater treatment systems entail the use of additives: acids and bases to control pH, polymers to aid settling and filtration, antifoam to reduce foaming, and nutrients to promote bug growth in the biological treatment systems. Systems for the control of pH were discussed in Section 3.5.

3.7.1 Equipment Description

The equipment required in chemical addition systems includes a storage tank and a mix tank (these may be the same), a method for pumping the additive, and a method for measuring and verifying flow rate. The additive can be moved by a metering pump, gravity flow, or a seal tank with an inert gas pad to pressure the fluid into the discharge line. Metering pumps are positive displacement pumps, and the flow rate is adjusted by changing the pump setting. If gravity or inert gas pressure is used as the driving force, a flow control valve is generally required. If the flow does not have to be varied during plant operation, sufficient pressure drop can be built into the line of a gravity or inert-gas-padded system to maintain proper flow.

For verification of flowrate, it is best to measure the flow directly by use of a graduated cylinder and stop watch. One practice is to divert the flow into the cylinder at a point as close as possible to the end of the additive pipe for a rate measurement. Another common practice is to pipe the additive into a graduated cylinder on the suction side of a metering pump or control valve. The cylinder is filled with the chemical and then the tank is isolated so that the additive system draws from the graduated cylinder instead of the tank.

Tanks holding chemical additives should have a level indicator. Periodic recording of the tank level allows the flow to be calculated. Of course, this method is too slow to be used when the flow rate is being changed, but it provides an easy way to verify the calibration during normal operation.

3.7.2 Design Parameters

In recycle water systems, additives are used to maintain water quality. Corrosion inhibitors are added that scavenge (combine with) oxygen from the water and coat the internal parts of the equipment with a protective film. Biocides are added to destroy microorganisms such as algae, fungi, bacteria, and slimes. Because these microorganisms can develop a tolerance for chemicals that are continuously fed, the biocides are usually injected in heavy doses two or three times per month. This minimizes the probability that the microorganisms will develop a tolerance. Dispersants are also added to prevent dissolved solids from precipitating on the surface of piping and equipment.

Polymers are long-chain hydrocarbon molecules that promote the flocculation and settling of suspended material. In the iron and steel industry, they are commonly used in clarifiers and settling basins and are sometimes used to aid filtration and centrifugation.

Polymer vendors are usually available to recommend the type of polymer and addition level for a specific application; however, the plant laboratory should run its own tests to verify these recommendations. Settling tests can be run easily by use of a jar test apparatus, and filtration tests also can be done easily with a lab filtration apparatus. When used as a settling aid in a clarifier or basin, most polymers have an optimum concentration for addition. If the polymer level goes below or above this optimum, it loses its effectiveness. In fact, an overdose of polymer can have the same effect as no polymer at all.[1]

At very low turbidities, polymers are ineffective coagulants. A sufficiently high concentration of suspended solids must be present for the particles to collide and form flocs. One reference suggested that a suspended solids level below 500 ppm may exhibit this problem.[2] If the level of suspended solids is too low, additional solids can be added in the form of clay or alum.[1]

Information available from several chemical additive manufacturers was obtained and is summarized in Table 3.7-1.

Polymers are rarely used as a vacuum filtration or centrifugation aid, but they are sometimes used for multimedia filters. In one application to high rate filtration, the addition of 5 ppm of polyelectrolyte at the filter inlet reduced the effluent suspended solids concentration from 28 to 17 ppm, and the oil concentration from 20 to 10 ppm. In this case, the filter media

TABLE 3.7-1. SUMMARY OF CHEMICAL ADDITIVE MANUFACTURER INFORMATION

Process	Vendor[a]	Brand name	Description	Physical state	Dosage, ppm (unless otherwise specified)
Coke plant	American Cyanamid	Magnifloc 835A	Anionic hig mol wgt polymer flocculant	Powder	0.5-0.75
	American Cyanamid	Magnifloc 577C	Cationic high mol wgt polymer flocculant	Water-based emulsion	5
	Betz	Polymer 1100	Anionic high mol wgt polymer flocculant	White powder	0.4-1.0
	Betz	Polymer 1165	Cationic polymer	-	2-20
	Betz	Polymer 1192	Cationic polymer	-	2-40
	Betz	Polymer 1195	Cationic polymer	-	2-20
	Betz	FT-174	Antifoam/defoamer	Liquid	5-25
	Betz	FT-166	Antifoam/defoamer	Amber liquid	5-25
	Betz	FT-300	Antifoam/defoamer	Liquid	5-50
	Betz	FT-786	Antifoam/defoamer	Liquid	5-50
	Petrolite	VEZ-D500	Antifoamer	Liquid	0.5-10
	Petrolite	VEZ-D109	Antifoamer	Liquid	0.5-10
Blast furnace recycle	American Cyanamid	Magnifloc 577C/507C	Cationic high mol wgt polymer flocculant	Water-based emulsion	2-10
	American Cyanamid	Magnifloc 835A	Anionic high mol wgt polymer flocculant	Powder	~0.5
	American Cyanamid[b]	Magnifloc 1563C	Cationic high mol wgt polymer flocculant	Powder	5-20 lb/dry ton
	American Cyanamid[b]	Magnifloc 1820A	Anionic high mol wgt polymer flocculant	Liquid emulsion	10 lb/dry ton
	Betz[b]	Polymer 1100	Anionic high mol wgt polymer flocculant	White powder	0.5-5.0 lb/ton sludge
	Betz[b]	Polymer 1110	Anionic high mol wgt polymer flocculant	White powder	0.5-5.0 lb/ton sludge
	Betz[b]	Polymer 1120	Anionic high mol wgt polymer flocculant	White liquid	0.5-5.0 lb/ton sludge
	Betz	Polymer 1115L	Anionic high mol wgt polymer flocculant	White liquid	0.3-1.0
	Betz	Polymer 1125L	Anionic high mol wgt polymer flocculant	White liquid	0.3-1.0
	Nalco	7735/603	Cationic coagulant	Yellow liquid	5-10/0.5-3.0
	Nalco	7766	Anionic emulsion flocculant	Cream liquid	0.5-3.0
	Zimmite	ZT-644	Anionic flocculant	-	0.2
	Petrolite	TOLFLOC	Anionic emulsion polymer	Liquid	0.2-10
BOF treatment	American Cyanamid	Magnifloc 1906N	Nonionic high mol wgt polymer flocculant	Liquid emulsion	0.5-1.0
	American Cyanamid	Magnifloc 577C/507C	Anionic high mol wgt polymer flocculant	Water-based polymer	1.0
	American Cyanamid[b]	Magnifloc 1563C	Cationic high mol wgt polymer flocculant	Liquid emulsion	5-10 lb/dry ton
	Betz[b]	Polymer 1100	Anionic high mol wgt polymer flocculant	White powder	0.5-5.0 lb/ton sludge
	Betz[b]	Polymer 1110	Anionic high mol wgt polymer flocculant	White powder	0.5-5.0 lb/ton sludge
	Betz[b]	Polymer 1120	Anionic high mol wgt polymer flocculant	White powder	0.5-5.0 lb/ton sludge
	Betz[b]	Polymer 1115L	Anionic high mol wgt polymer flocculant	White liquid	0.3-1.0
	Betz[b]	Polymer 1125L	Anionic high mol wgt polymer flocculant	White liquid	0.3-1.0
	Nalco	7735/603	Cationic coagulant	Yellow/clear liquids	5-10/0.5-3.0
	Nalco	7766	Emulsion flocculant	Cream liquid	0.5-3.0
	Zimmite	ZT-636 or 637	Anionic flocculant	White powder	0.2

TABLE 3.7-1 (continued)

Process	Vendor[a]	Brand name	Description	Physical state	Dosage, ppm (unless otherwise specified)
Hot forming	American Cyanamid	Magnifloc 905N	Nonionic high mol wgt polymer flocculant	Powder	0.1-0.5
	American Cyanamid	Magnifloc 835A	Anionic high mol wgt polymer flocculant	Powder	0.1-0.5
	American Cyanamid	Magnifloc 505C	Cationic flocculant	Water-based polymer	5-10
	American Cyanamid	Magnifloc 507C	Cationic flocculant	Water-based polymer	5-10
	American Cyanamid	Magnifloc 572C	Cationic high mol wgt polymer flocculant	Water-based polymer	~5
	Betz[b]	Polymer 1100	Anionic high mol wgt polymer flocculant	White powder	0.5-5.0 lb/ton sludge
	Betz[b]	Polymer 1110	Anionic high mol wgt polymer flocculant	White powder	0.5-5.0 lb/ton sludge
	Betz[b]	Polymer 1120	Anionic high mol wgt polymer flocculant	White powder	0.5-5.0 lb/ton sludge
	Betz	Polymer 1115L	Anionic high mol wgt polymer flocculant	White liquid	0.5-1.0
	Betz	Polymer 1125L	Anionic high mol wgt polymer flocculant	White liquid	0.5
	Betz	Polymer 1175	Cationic coagulant	Liquid	0.5-2.0
	Betz	Polymer 1180	Cationic coagulant	Liquid	0.5-2.0
	Betz	Polymer 1190	Cationic coagulant	Clear liquid	0.5-2.0
	Nalco	7735/603	Coagulant clarifier	Yellow/clear liquid	1-50
	Nalco	7763/7766	Flocculant clarifier	- /cream liquid	0.5-3.0
	Zimmite	ZT-651/ZT-695	- /cationic flocculant	- /liquid	0.25/1.0
Acid pickling	American Cyanamid	Magnifloc 835A	Anionic high mol wgt polymer flocculant	Powder	0.5
	American Cyanamid	Magnifloc 1820A	Anionic high mol wgt polymer flocculant	Liquid emulsion	0.5
	American Cyanamid	Magnifloc 836A	Anionic high mol wgt polymer flocculant	Powder	0.5
	American Cyanamid	Magnifloc 1839A	Anionic high mol wgt polymer flocculant	Liquid emulsion	0.5
	Betz	Polymer 1100	Anionic high mol wgt polymer flocculant	White powder	0.4-3.0
	Betz	Polymer 1125L	Anionic high mol wgt polymer flocculant	White liquid	0.2-1.0
	Zimmite	ZT-636/ZT-637	Anionic flocculant	Powder	0.2-0.5

[a] References 4 through 8.

[b] Used to help dewater sludge.

also seemed easier to backwash when coagulants were used.[3] This application was on oily wastewater from the strip mill collection sump.

When an antifoam is used, the objective is usually to keep the foam from becoming a problem by using the minimum amount of chemical addition possible. Many plants have opted to use a water spray instead of antifoam to minimize foaming problems. Foaming problems generally occur in splitter boxes, clarifier center wells and biological basins. In some instances, spraying these areas with recycled water has shown to be as effective as antifoam, and cheaper.

Nutrient addition is oftentimes required in a biological treatment pond. In addition to food, the bugs must have phosphorous and nitrogen. A coke plant waste treatment system generally has enough nitrogen, but phosphorous (in the form of phosphoric acid) usually must be added. These nutrients are controlled by measuring their concentration in the effluent from the biological ponds. Their levels will depend on the specific system, but in general, residual phosphorous should amount to about 1 ppm in the biological pond effluent.

3.7.3 O&M Problems and Solutions

Because the flow rate of all the chemical additives (e.g., polymers) discussed in this section is low, it is sometimes difficult to determine if they are flowing. Ideally, these chemicals should be introduced above the level of the liquid to which they are being added so the operator can see them falling from the end of the pipe into the tank and thereby verify the flow. The low flow also makes the lines subject to freezing in the wintertime, and adequate freeze protection must be provided. At one plant, rubber hoses were used to transport polymer from the discharge of a piston type metering pump. The operator could put his hand on the hose and feel the pulsations to verify that polymer was flowing. If the hose should freeze, the operator could disconnect the line and bring it into a heated room to thaw.

Some plants are using fully automated polymer systems in which the polymer is automatically added and mixed as needed. This kind of system requires very little attention. The operator should, however, vary the polymer flow as the wastewater flow changes. In one plant, the polymer flow was simply set at a level corresponding with the maximum wastewater flow rate so that the operator would not have to make adjustments as the flow changed. This polymer overdosing may not have harmed its effectiveness, but any plant using this technique should verify the effect of overdosing on settling rate.

The vendor's instructions regarding the specific polymer in use, should be followed closely. Rapid mix instructions are usually fairly specific. When the polymer is first mixed, the mixing must be sufficient to activate the polymer, but excessive mixing can shear the polymer and damage its effectiveness. Many polymers must be aged for 12 to 24 hours after they are mixed to achieve maximum efficiency. This aging requires two tanks: one for mixing and aging the polymer, and one from which to feed the polymer. One plant uses a single tank, and feeds the polymer from the tank in which it was mixed. This plant has been able to select polymers that would operate properly under this condition.

The concentrated polymer from the vendor has a shelf life that generally ranges from 6 months to a year. Care should be taken not to use a polymer that is so old it has lost its effectiveness. Most polymers also will be damaged by freezing, and they should be stored in an area where they are protected from freezing.

Every plant that uses polymers should have a jar test apparatus in its laboratory and personnel trained to use this equipment to evaluate polymers. A number of vendors sell polymers and provide the jar test apparatus (see Figure 3.1-2) to evaluate their polymers for application in a particular plant. An evaluation performed by plant personnel may be more objective, however, and would certainly provide results for comparison with those of the vendor representative. This test will also show if there is a problem with the polymer currently being used, either because of poor preparation practices in the plant or because the polymer has lost its effectiveness because it is too old, has been frozen, etc.

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3.8 ALKALINE CHLORINATION

3.8.1 Pollutants Removed

Alkaline chlorination is a treatment scheme whereby a prepared, chlorinated water stream that is buffered to an alkaline pH is mixed with a wastewater stream to a controlled pH range for the purpose of removing desired chlorine-demanding pollutants such as ammonia, cyanide, and phenol. The process is very similar to breakpoint chlorination, except that the pH is controlled in an alkaline range, rather than at neutral conditions. Chlorination in general has seen a great deal of use for disinfecting potable water and for control of taste, odor, ammonia, cyanide, phenols, and other materials exerting a chlorine or oxygen demand in industrial wastewaters.

The breakpoint is the point at which further addition of chlorine produces a residual as free chlorine rather than a combined chlorine residual, as shown in Figure 3.8-1. When water is chlorinated to the breakpoint, a series of oxidation-reduction reactions take place that oxidize the pollutant of concern while reducing the chlorine species. The major pollutants of concern at a steel plant wastewater system include ammonia-nitrogen (NH_3-N), cyanides (HCN), and phenols. The oxidation of NH_3 yields end products of nitrogen gas (N_2) and hydrochloric acid (HCl) by the overall reaction:

$$2NH_3 + 3Cl_2 \rightarrow N_2 + 6\ HCl$$

The overall oxidation reaction for the cyanide ion is as follows:

$$2CN^- + 5\ Cl_2 + 8OH^- \rightarrow 10\ Cl^- + 2CO_2 + N_2 + 4H_2O$$

The mechanics of breakpoint chlorination can be visualized by referring to Figure 3.8-1. In this figure, the residual chlorine concentration and ammonia concentration are plotted as a function of chlorine addition. This plot shows NH_3-N as the material being oxidized, but any chlorine-demanding compound will produce a similar, although less-pronounced, chlorine residual curve.

The chlorine reduction reaction occurs in zone 1 as free chlorine (HOCl or OCl^-) is introduced into the polluted water. (At pH of 8.0, approximately 80 percent of the free chlorine will be present as OCl^-.) The principal

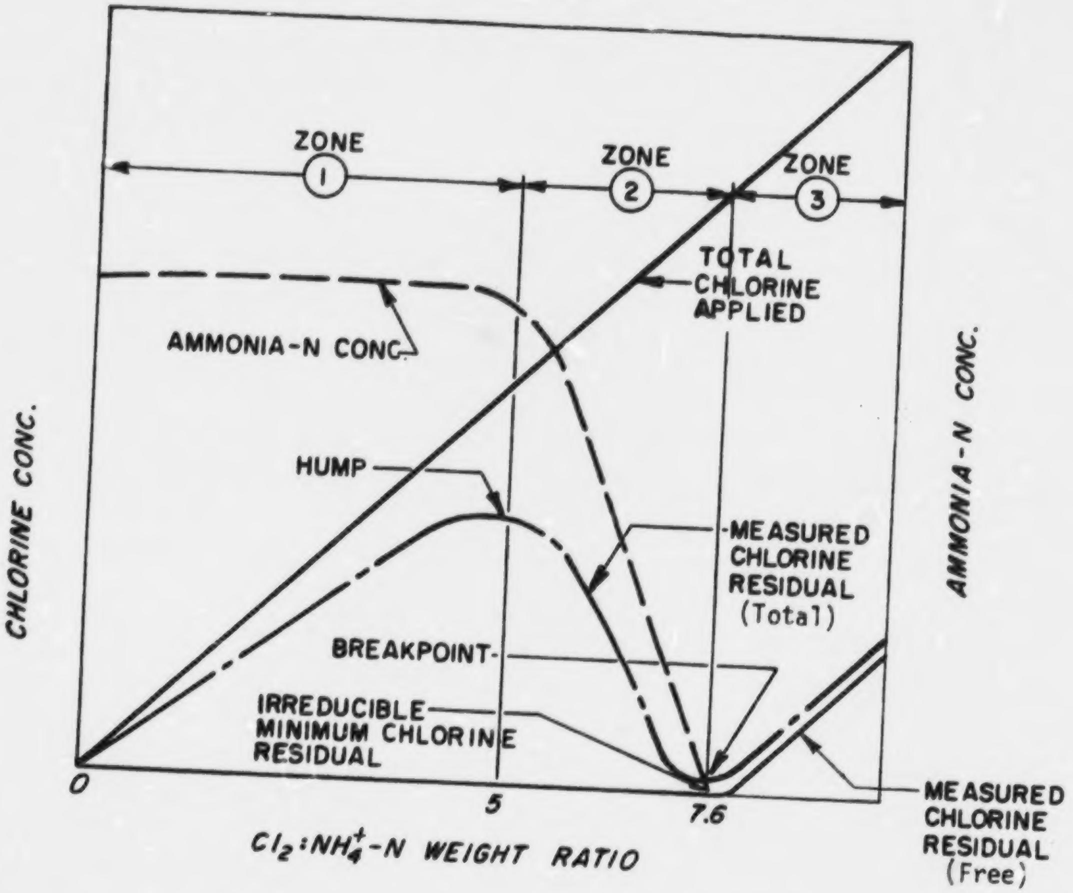

Figure 3.8-1. Theoretical breakpoint chlorination curve.

reaction in zone 1 is the oxidation/reduction of NH_3/OCl^- to form monochloramine (NH_2Cl) and hydrochloric acid (HCl). The chlorine is now present in a combined form and is no longer available for oxidation of ammonia. This reaction continues until all of the NH_3-N has been partially oxidized to monochloramine.

Further chlorine addition completes the oxidation of the monochloramine in zone 2 to dichloramine ($NHCl_2$), nitrogen trichloride (NCl_3), HCl, and nitrogen gas (N_2). At this time, the NH_3-N concentration is reduced as N_2 is driven from the wastewater and the chlorine residual is reduced as HCl is produced. The chlorinated products of reaction are in the combined form as all free chlorine applied is consumed in the oxidation reaction.

Zone 3 displays an increase in the free available chlorine residual, signifying that all chlorine demands have been satisfied and the "breakpoint" has been reached. The free chlorine residual will now parallel the chlorine application curve with an increase in the chlorine dosage, producing a corresponding increase in the free residual. At this point, the wastewater is free of NH_3-N, CN^-, and organic material demanding chlorine with end products present as N_2, HCl, CO_2, chlorine salts, and possibly chlorinated organic compounds.

3.8.2 Governing Design Parameters

Design of an adequate alkaline chlorination system requires a combination of physical and chemical parameters. The major areas of concern in such a design include:

- Chlorine demand of wastewater constituents
- Configuration of chlorinator
- pH control of the reaction
- Chlorine contacting mechanism and reaction time
- Process control

Chlorine Demand of Wastewater Constituents--

Many constituents in steel plant wastewater will be oxidized by chlorine and collectively constitute the chlorine demand for the waste. Some pollutants found in steel wastewater streams that will reduce the available chlorine include ammonia, cyanides (free form only), thiocyanates, sulfides, sulfates, and phenol. Chemical or biological treatment processes can reduce the loading of some of these pollutants, and incorporating pretreatment will produce more dependable control at the chlorination chamber and a lower cost chlorination process. The major pollutants of concern in alkaline chlorination are the cyanides and ammonia. As shown previously in Figure 3.8-1, 7.6 parts (by weight) of chlorine are required theoretically to oxidize 1 part of ammonia to N_2; for complete oxidation of cyanide to CO_2 and N_2, 6.82 parts of chlorine are required for each part of cyanide.[1] Oxidation of cyanide to cyanate (a relatively harmless form) requires only 2.7 parts of chlorine per part of cyanide.[2] Complete oxidation of phenol requires 10 parts of chlorine per part of phenol.[3] Thus, if complete oxidation of ammonia and cyanide is desired and only these pollutants are present, the chlorine dosage required is calculated as follows:

Given NH_3 concentration = 120 mg/liter

CN^- concentration = 6 mg/liter

Required chlorine concentration = 120 mg/liter (7.6) + 6 mg/liter (6.82)

= 953 mg/liter

Based on a wastewater flow rate of 400 gal/min, the chlorine addition rate is = 953 mg/liter x 3.785 liter/gal x 400 gal/min ÷ 1000 mg/g ÷ 454 g/lb

= 3.18 lb/min

≅ 4580 lb/day

The chlorine-to-ammonia ratio is equal to 953 mg/liter ÷ 120 mg/liter, or 7.9 $Cl:NH_3$. Due to other chlorine demands, mixing, pollutant variation, and other reasons, a $Cl:NH_3$ ratio of from 8:1 to 10:1 is usually maintained. The actual demand exerted by a waste is best determined by actually taking a sample to the breakpoint and then calculating the required dosages.

Configuration of the Chlorinator--

The configuration of the chlorination system is extremely important for optimum and safe operation. Because of the required quantities of chlorine for treating steel wastewaters, liquid chlorine will be used as the feed stock, with a chlorine evaporator to transform the liquid to gaseous Cl_2.

(Evaporators are generally required when more than 1500 lb Cl_2/day is needed.[4]) Chlorine gas is delivered to a chlorine metering device that meters the chlorine gas into a clean water stream to produce hypochlorite (HOCl). The HOCl will dissociate to H^+ and OCl^-; the dissociation constant being dependent on pH. Prior to alkaline addition, the pH of the chlorine solution will be low due to the presence of the H^+ radical (present as HCl), and the predominant form will be HOCl.

The concentration of chlorine dissolved in the water at this point is up to 8,000 mg/liter. An injector is placed in line to draw a vacuum on the gas metering device and thus mix the chlorine with a water source. Lime (CaO) or sodium hydroxide (NaOH) is then added to the chlorinated water to raise the pH, and this pH-adjusted stream is mixed with the wastewater. Addition of lime yields calcium hypochlorite (CaOCl), while addition of sodium hydroxide yields sodium hypochlorite (NaOCl). A schematic showing chlorine tank car unloading, chlorine evaporators, chlorine injectors, and the chlorine contact tank is shown in Figure 3.8-2.

Several items are important in this system. Because chlorine dissolved in water will cause a decrease in pH, a buffer must be added. In addition, the breakpoint reaction produces HCl, which also causes a reduction in pH. Control of pH in the reaction is extremely important, and as such, the chlorine feed solution must be highly buffered to maintain a pH of 9.0 to 10.0 prior to delivery to the waste stream. This high pH and the calcium or sodium added to the system make it extremely likely that deposition will occur in the chlorinator lines. Good operating and maintenance (preventive) practices and availability of spare equipment help minimize the problems.

The chlorine injector water is another important consideration. After injection, the chlorine concentration in the injector water will be on the order of 3,500 to 4,000 mg/liter. Thus, the quantities of injector water required can be significant. It is important, therefore, to provide an injector water source that does not exhibit a large chlorine demand in order to keep the volume of injector water to a minimum.

pH Control of the Reaction--

Control of pH during breakpoint chlorination is both difficult and important. It is difficult because end products of the reactions are acidic, requiring the addition of alkaline material to the chlorine feed and reaction

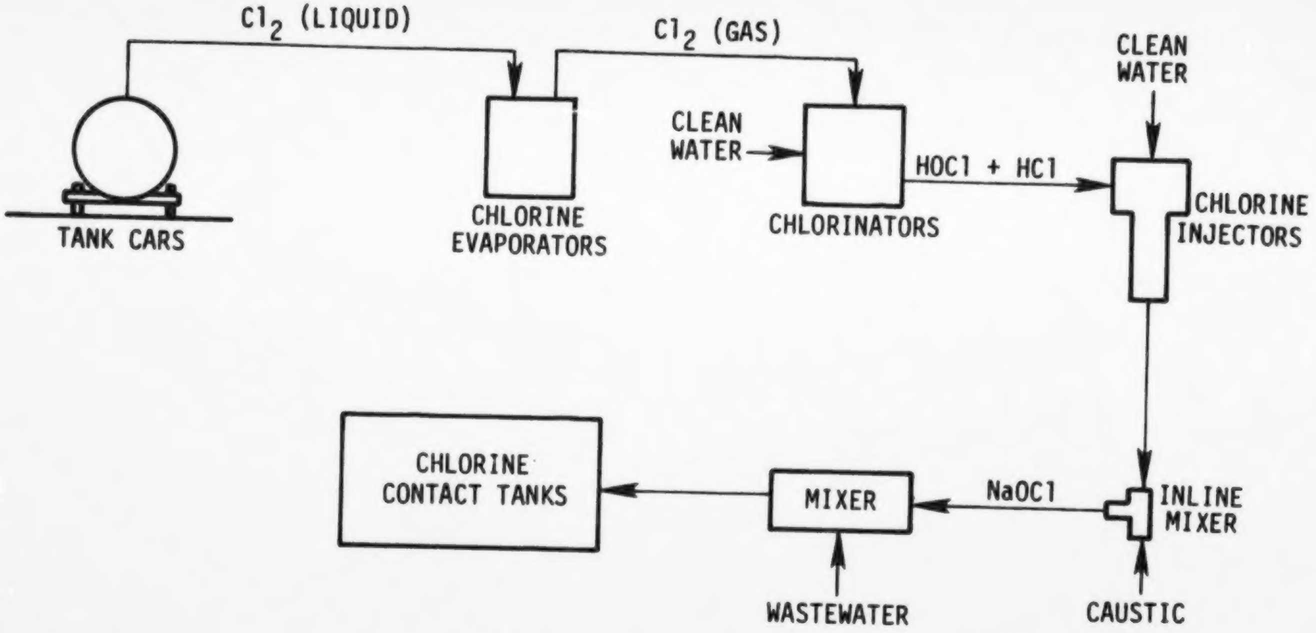
Cl_2 (LIQUID)
Cl_2 (GAS)
CLEAN WATER
CLEAN WATER
TANK CARS
CHLORINE EVAPORATORS
CHLORINATORS
HOCl + HCl
CHLORINE INJECTORS
CHLORINE CONTACT TANKS
MIXER
NaOCl
INLINE MIXER
WASTEWATER
CAUSTIC

Figure 3.8-2. Schematic showing chlorine flow for an alkaline chlorination system.

chamber to neutralize the acid. The time allowed for the reactions to go to completion can be great. The lag time between the point at which pH is monitored and the point at which alkaline material is added can make a pH control loop difficult. Control of pH is important because at a low pH, undesirable end products of the ammonia and cyanide reaction are produced and the reaction rates are slow. At a high pH, it is possible to form a cyanide complex that is extremely stable and difficult to remove from the water.

The most popular method of pH control is pH adjustment of the liquid streams entering the chlorine mixing chamber, i.e., the waste stream and the chlorine injector water. Lime is a common alkalinity source. The pH of the injector water will be made alkaline up to a pH of approximately 9.0. The lime addition to the waste stream can be based on bringing the water up to the desired pH and then adding excess lime to neutralize the HCl produced during the reaction.

Optimum pH for the NH_3 oxidation reaction is 7.0 to 8.0. For cyanide oxidation, the optimum pH range is 8.5 to 10.0.[2] Maintaining the chlorination reaction at less than a pH of 7.0 will promote the formation of undesirable end products. The products of NH_3 oxidation can include mono or dichloramines, and nitrogen trichloride. The extremely toxic compound nitrogen trichloride is the main end product at low pH levels. The main product of concern at low pH in the cyanide reaction is cyanogen chloride (CNCl), which also is a toxic gas.

At high pH's (greater than 9.0), it is possible to form iron complexes with cyanide.[5] This complex is a combined form of cyanide and will not be oxidized in alkaline chlorination. Thus, to provide the maximum reaction rates while minimizing the formation of undesirable products, the pH of the alkaline chlorination process should be maintained between 8.0 and 9.0 if both cyanide and ammonia are being oxidized, and between 7.0 and 8.0 if only ammonia is being oxidized.

Chlorine Contacting Mechanism and Reaction Time--

A variety of chlorine injector water/wastewater mixing arrangements is possible. The goal is to provide rapid and complete mixing upon chlorine introduction. After the initial mixing, plug flow of the wastewater is desirable in the contact or reaction tanks to ensure that at least 90 percent of the wastewater is reacted with the chlorine for the required time.[4] A schematic of an alkaline chlorination system at a visited plant is shown in Figure 3.8-3. This system also has deep-bed gravity filters for the treatment of other plant wastewaters.

Reaction time for NH_3 is 10 minutes. The CN^- reaction takes considerably longer, with reaction times of 60 minutes required to oxidize the cyanide to cyanate, and up to 180 minutes for complete oxidation of cyanide to CO_2 and N_2. Consideration of reaction time is necessary when deviating from design flow rates and when large amounts of injector water are added to the system.

Process Control--

Process control mainly involves control of pH and control of chlorine feed rates. It is common practice to control both pH and chlorine addition by monitoring influent NH_3. Many installations find the continous monitoring of NH_3 unreliable and instead perform grab sampling of the influent. Chlorine addition is then set manually or is monitored by the oxidation reduction potential (ORP see Section 5.4) of the liquid stream. Lime or sodium hydroxide is added for pH control.

A more certain method of process control includes monitoring pH in the reaction tank, with alkaline addition as needed, and the free and total chlorine residual in the effluent. The presence of free chlorine in the effluent signifies that adequate chlorine has been added to achieve breakpoint. After breakpoint, the free chlorine residual can be adjusted by adjusting the chlorine feed rate (there is a 1-to-1 correspondence of the two). Operation within a reasonable pH range can be ascertained by the amount of combined chlorine present in the effluent. Combined chlorine (total chlorine minus free chlorine) represents the presence of undesirable end products. The quantity of such end products is usually dependent on pH.

3.8.3 Treatment System Capabilities

A properly operated alkaline chlorination system can achieve complete oxidation of NH_3 and CN^- to N_2, CO_2, and HCl. Because this level of oxidation is dependent on many factors, however, less than complete oxidation is observed at least for a portion of the time. A summary of available data from alkaline chlorination systems is given in Table 3.8-1. The wide range in the treament capabilities shown in the table signifies both the differences between treatment systems and the sensitivity of the chlorination reaction.

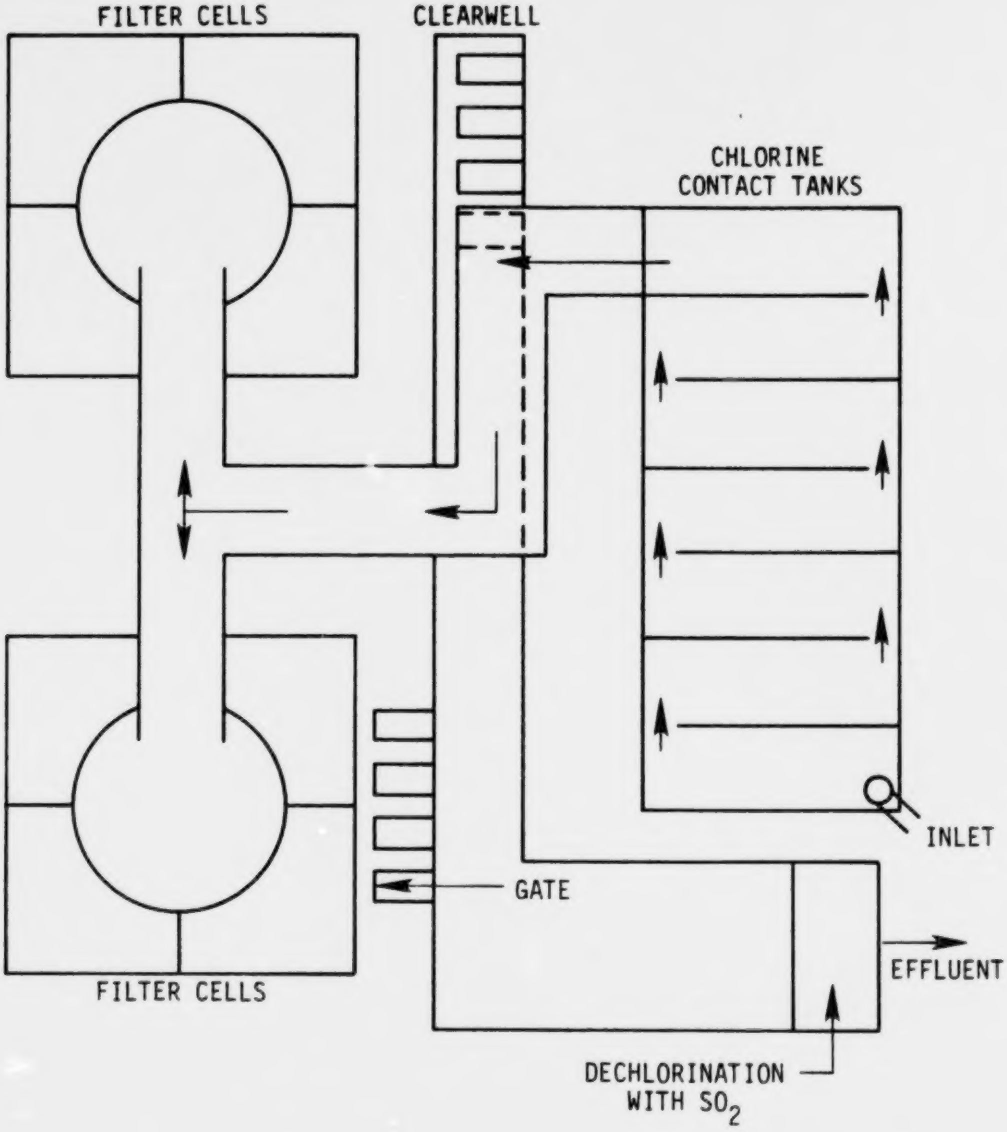
FILTER CELLS
CLEARWELL
CHLORINE CONTACT TANKS
INLET
GATE
EFFLUENT
FILTER CELLS
DECHLORINATION WITH SO_2

Figure 3.8-3. Schematic of an alkaline chlorination/filtration system.

TABLE 3.8-1. TREATMENT CAPABILITIES OF ALKALINE CHLORINATION SYSTEMS

Compound	Influent concentration, mg/liter	Effluent concentration, mg/liter	Removal, %	Reference
Ammonia[a,b]	115	4.1	96.4	1
Cyanide[a,b]	5.6	0.02	99.6	1
Ammonia[b,c]	72	1.2	98.3	1
Cyanide[b,c]	4.2	0.25	94.0	1
NH_3	1.91	0.806	57.8	6 (plant 0946 A)
Phenol	0.132	0.014	89.4	6 (plant 0946 A)
Cyanide	1.43	0.005	99.6	6 (plant 0946 A)
NH_3	25	7.9	68.4	6 (plant 0684 H)
Phenol	2.50	2.00	20.0	6 (plant 0684 H)
Cyanide	0.301	0.227	24.6	6 (plant 0684 H)
Cyanide[b]	3.38	0.12	87.5	5
Cyanide[b]	4.17	0.514	87.7	5
NH_3	74	<1	>98.6	d
NH_3[b]	332	175	52	7
Phenol[b]	88	0.40	>99.6	7
CN^-	32	4.0	87	7

[a] Single-stage system.

[b] Mean values.

[c] Two-stage system.

[d] Actual measured values recorded during plant visit for this study.

3.8.4 Types of Upsets/Problems and Their Causes

Many upset conditions can occur during alkaline chlorination, the most severe of which is inadequate treatment. Simply stated, inadequate treatment of the waste will result whenever the chlorine dosage is insufficient to meet the chlorine demand of the waste. (Even loss of pH control can allow complete oxidation, although undesirable end products will be formed.) Insufficient chlorine dosage can be caused by any number of conditions:

- Failure of chlorine injection system
- Increase in NH_3/CN^- concentration of waste
- Increase in flow rate of waste
- Introduction of biological floc from coke plant treatment systems (when practiced)
- Introduction of organic constituents
- Introduction of other chlorine demanding compounds

The easy solution to these problems is to increase the chlorine feed rate. Injection system failures can be caused by scaling of the system components, which leads to inadequate delivery. In this situation, a spare chlorinator can be temporarily utilized. Variations in the concentrations of chlorine demanding constituents is best resolved by reducing the wastewater flow rate and increasing the chlorine dosage until free chlorine is observed in the effluent. When free chlorine is present, final flow and chlorine dosage adjustments can be made to retain stable operation. Biological floc entering the system will demand large quantities of chlorine. This situation will require upstream attention.

Upsets due to loss of pH control include the evolution of noxious fumes and formation of undesirable end products at low pH, and the formation of untreatable iron/cyanide complexes at high pH. Because only free cyanide can be treated in the system, the formation of such complexes is devastating on system performance. Although extremely hazardous for the employee, operation at low pH will still accomplish control of the desired pollutants at less-than-optimum performance conditions.

Another operating problem with alkaline chlorination is the formation and deposition of precipitate, usually CaCl or NaCl. Thus, the velocity of the treated waste must be kept above a minimum velocity to ensure that the solids are not deposited in the chlorination chambers. Subsequently, it can be observed that the suspended solids loading in the effluent can be greater at times than influent loadings due to agitation of the settled solids. Periodic inspection and cleanout (when necessary) of the chambers should be performed.

REFERENCES FOR SECTION 3.8

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5. Wong-Chong, G. M., and S. C. Caruso. Evaluation of EPA Recommended Treatment and Control Technology for Blast Furnace Wastewater. Journal of the Environmental Engineering Division, ASCE, Vol. 104, No. EE2, Proc. Papa 13680, April 1978, pp. 305-321.

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7. Zwikl, J. R., et al. Physical/Chemical Treatment of Coke Plant Wastewater. Presented at EPA Symposium on Iron and Steel Pollution Abatement Technology for 1982, Pittsburgh, Pennsylvania, November 16-18, 1982.

3.9 OIL SKIMMING AND RECOVERY

Oil-contaminated wastewater comes from several sources in a steel mill. The primary sources are as follows: rolling oils used at hot and cold rolling mills (oil adheres to the scale during rolling operations and is flushed with the scale into receiving flumes), and spills and leaks of oils used in heat treatment; oils resulting from degreasing operations, hydraulic oils used for positioning devices or press operations, lubricants used throughout the plant, and fuel oil used in the boiler plant.[1]

3.9.1 Equipment Description

The steel industry removes oils and greases from process wastewaters by several methods, including oil skimming, air flotation, decanting, and clarification with ferric hydroxide floc. This section deals with oil skimming, specifically by paddle, rope, and belt skimmers, which are widely used at the plants visited.

As the name implies, skimmers remove only the oil that is on the surface of the wastewater. Skimming normally takes place in a tank or lagoon designed to allow the floating oil to rise and remain on the surface while the water flows to an outlet located below the floating layer.[2] Thus, skimming devices are suitable for removal of nonemulsified or insoluble oils from wastewaters.

The removal efficiency of a skimmer is partly a function of the retention time of the water in the tank. Because larger, more buoyant particles require less retention time than smaller particles, efficiency also depends on the composition of the wastewater.

Figure 3.9-1 shows the major components of an oil flotation and skimming system. The wastewater first enters a primary surge tank, which provides equilization. In this tank, oil droplets or globules that are easily separated will accumulate on the surface of the water and be decanted periodically. From this primary surge tank, the water flows to an API type separator, which is a long rectangular tank with a long retention time that allows smaller oil droplets sufficient time to float to the surface. At the far end of this primary settling tank, an underflow baffle retains any oil that is on or near the surface of the liquid. Wastewater flows under this first baffle and then across an overflow baffle. The overflow baffle can be adjusted to control the liquid level in the tank. A skimmer operates just

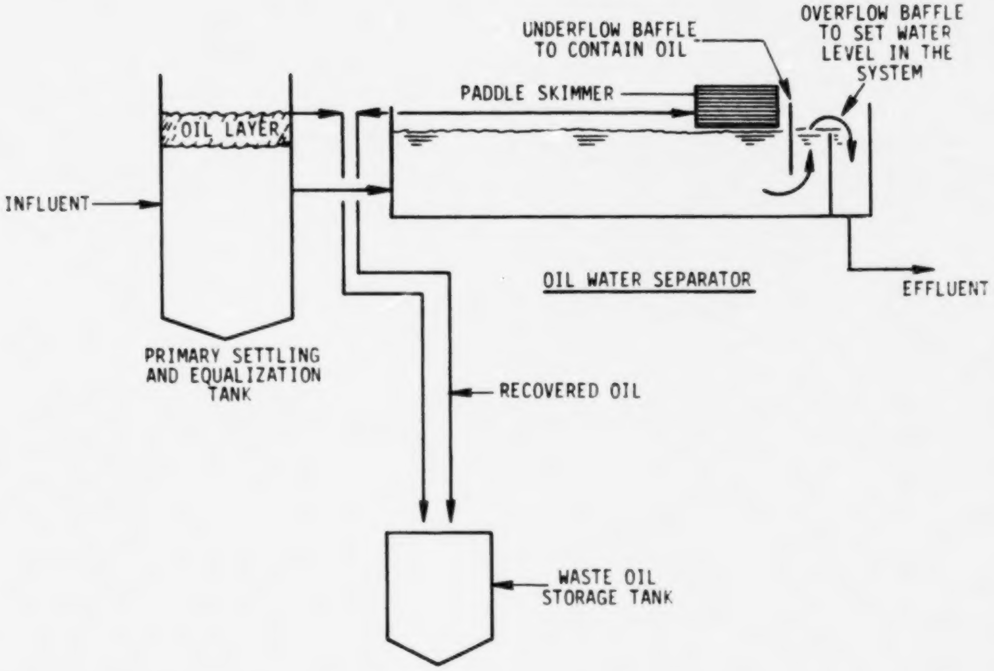

UNDERFLOW BAFFLE TO CONTAIN OIL
OVERFLOW BAFFLE TO SET WATER LEVEL IN THE SYSTEM
PADDLE SKIMMER
OIL LAYER
INFLUENT
OIL WATER SEPARATOR
EFFLUENT
PRIMARY SETTLING AND EQUALIZATION TANK
RECOVERED OIL
WASTE OIL STORAGE TANK

Figure 3.9-1. Components of an oil skimming system.

behind the underflow baffle to remove surface oil. Figure 3.9-1 shows a paddle skimmer, but other types of skimmers also can be used at this point. Induced by gravity, oil from the primary settling tank and the skimmer usually flows in a trough leading to an oil storage tank.

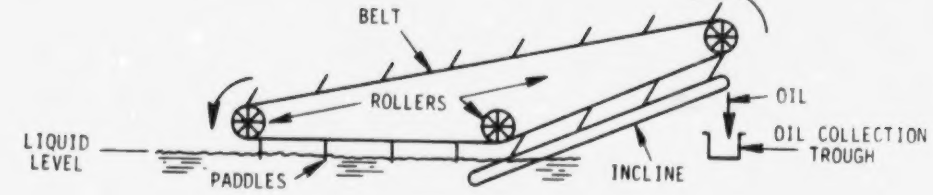
Figure 3.9-2 shows three common skimmer configurations. The paddle skimmer consists of a belt containing paddles that are drawn across the top of the wastewater to collect oil. These paddles scrape the oil up an incline, where it is dumped into the trough. This is one of the more complicated skimmer configurations, but it also does a very thorough job over a given liquid surface.

A rope skimmer consists of a flexible plastic tube that is fabricated to attract oil, but not water. This tube is shaped into a closed loop that continuously moves through the water in a vertical eliptical fashion. The oil that the tube picks up at the water surface as it exits the water is scraped off between the wheels that drive the tube. In some versions, the tube (or rope) passes through close-tolerance loops that remove the oil from the tube. The clean tube is then returned to the water to pick up more oil. The tube skimmer has the advantage of being able to snake over and around floating debris to pick up oil. Rope skimmers in deep scale pits must be long enough to reach the water even during low pit level. Because the tube floats, it is not sensitive to changes in the liquid level.[2]

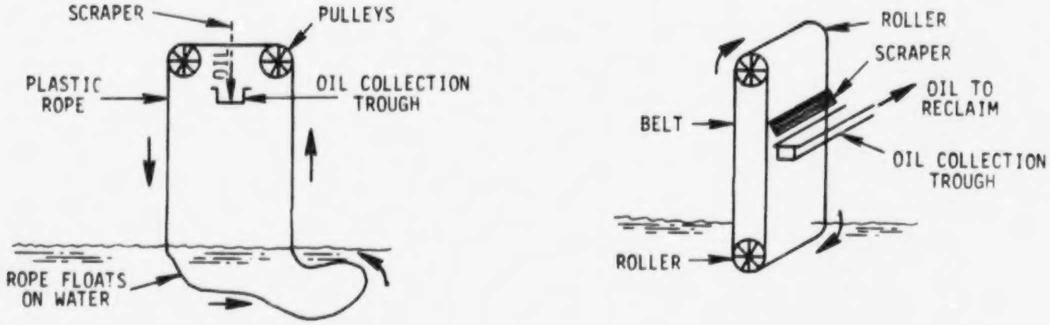
A belt skimmer consists of an endless vertical belt, one end of which is dipped into the water to pick up oil and grease. A scraper blade at the other end of the belt removes the oil and grease.

The wastewater discharge from rolling mills, which contains both oil and suspended solids, is sometimes treated in lagoons that provide enough residence time to allow the suspended solids to settle out and the oil to float to the surface. In this application, skimmers are located near the discharge end of the lagoon to remove oil. A floating baffle is sometimes stretched diagonally across the discharge end of the lagoon to direct any floating oil toward the skimmers. Adsorbing booms are sometimes used on the overflow baffle following the skimmers. As the water flows through these booms, the residual oil is adsorbed onto the material of the booms.

Floating booms are sometimes used at outfalls before discharged wastewater enters a receiving body of water. These floating booms are stretched out in an arc that is anchored on both sides of the outfall. This provides


BELT
ROLLERS
OIL
LIQUID LEVEL
OIL COLLECTION TROUGH
PADDLES
INCLINE

PADDLE SKIMMER


SCRAPER
PULLEYS
OIL
PLASTIC ROPE
OIL COLLECTION TROUGH
ROPE FLOATS ON WATER
ROLLER
SCRAPER
OIL TO RECLAIM
BELT
OIL COLLECTION TROUGH
ROLLER

ROPE SKIMMER

BELT SKIMMER

Figure 3.9-2. Three common skimmer configurations.

a means of capturing any residual oil that was not picked up previously. Because oil can spread out very thinly on the surface of water (a thickness of one molecule), a small amount of oil floating to the surface can make an unsightly slick. Floating booms at the outfall help capture any droplets that may cause such a condition.

3.9.2 Governing Design Parameters

Because skimmers only remove surface oil, they must be installed in locations where oil has had the opportunity to rise to the surface of the wastewater. Skimmers normally contact only a small fraction of the surface of the water; therefore, floating oil should be directed to the skimmer (e.g., by floating baffles). Paddle skimmers must be adjusted so that the paddles just scrape the surface of the water, but it is also important that the entire length of the paddle contact the water surface.

Because skimmers operate wet, provisions must be made for freeze protection in the wintertime. An ice buildup on the skimmers can cause mechanical failure. In some cases, thawing is achieved by spraying low-pressure steam or water on the surface of the tank near the skimmer.

Provisions should be made for manual removal of the oil from the liquid surface with a vacuum hose if the skimmer should fail or if the weather becomes so cold that it cannot be thawed out. This usually involves having a walkway near the skimmer to provide easy access to the surface of the wastewater.

3.9.3 Operation and Maintenance Problems and Solutions

Because of their simplicity, skimmers are very reliable. The skimming mechanism requires periodic lubrication, adjustment, and replacement of worn parts. During the winter, heating is usually required to keep the skimmer from freezing, or if this is not possible, a backup removal scheme (e.g., vacuum truck) should be available.

Most of the operating problems of a skimmer are easily diagnosable. A skimmer that is turned on but not operating is probably indicative of motor failure, chain or belt breakage, or a shear pin failure. The paddle skimmer should be checked to ensure that none of the blades is missing and that each scraper blade touches the water for the full length of the blade; replacement or adjustment of the blades may be necessary. A check also should be made to see if oil is being lost as the scraper blades come up the incline. Such oil loss can be due to physical faults in the incline or the scraper blades or to poor alignment.

Rope skimmers should be checked to insure that the rope is not rubbing against an object that could scrape off collected oil or abrade the rope. Debris in scale pits and skimming basin (observed at two skimming systems) caused the oil to be scraped off the tubes and fall back into the pits/basin. The inspection should observe the rope for one full revolution to ensure that it is not abraded at some point.

At one plant, the operator said that the plant's rope skimmers, which are effective, could be more effective if the tubes could penetrate the water surface better. Observation of the skimmer indicated that the rope occasionally floats entirely on the surface without dipping down into the water. This can be caused by the accumulation of an oil layer. The amount of oil picked up during these times is much less than when the skimmer penetrates and comes up out of the water. The operator said the plant is going to experiment by injecting some light-weight antifreeze type fluid into the plastic tubes to provide additional weight for better tube immersion. They also are hoping that the fluid will allow the skimmer to operate better at subfreezing temperatures.

Belt skimmers should be observed for one full revolution to check for rips, holes, or other faults in the belt. The scraper blade on the belt skimmer should be checked to ensure that it is removing the oil from the belt.

The skimmed oil usually falls into a trough that drains into a collection tank. These troughs must be kept clean enough so that the oil does not build up and overflow. The collection tank should be checked periodically to be sure it is not full.

Floating and adsorbent booms wear out and/or become ineffective as a result of saturation and must be replaced periodically. A boom that is encircling an outfall should be checked where it attaches to the shore.

Someone should inspect each skimmer daily. The plant also should have access to a vacuum truck so that any oil that is missed by the skimmer and is accumulating somewhere on the surface of the water can be removed when necessary. The vacuum truck can also be used as an emergency measure if the skimmer goes down.

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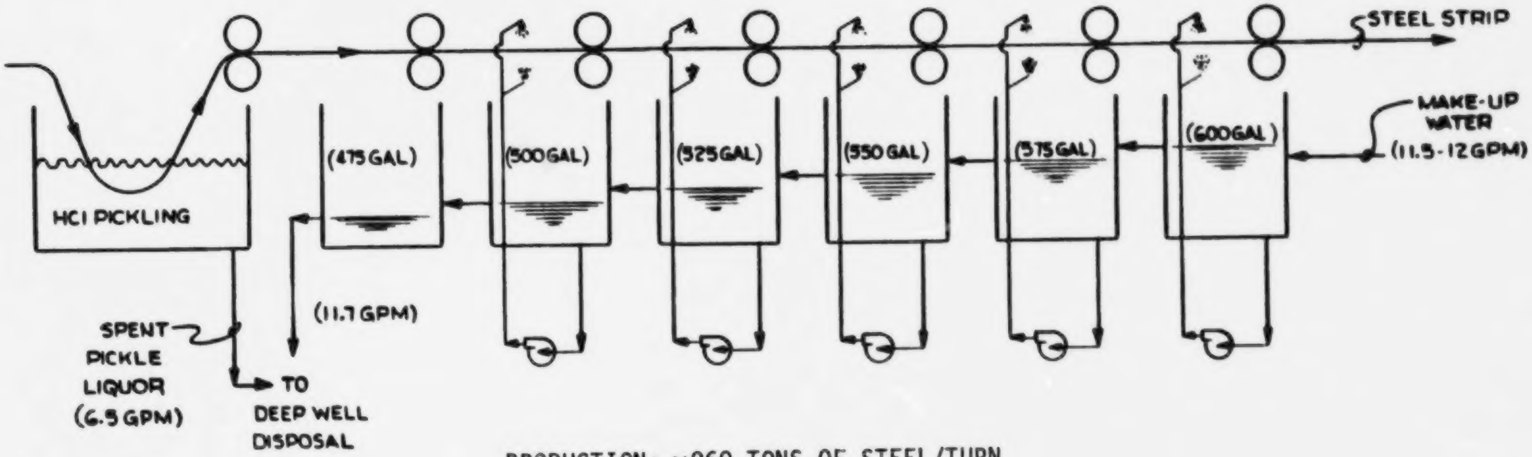
3.10 CASCADE RINSE

Cascade rinse is a form of water recycle. This term is used exclusively in the acid pickling subcategory. When steel coils undergo acid pickling (see Section 2.5), they are first pulled through the pickling tank and then through a series of rinse tanks. Prior to the implementation of cascade rinse, each of the rinse tanks was supplied by a separate water line and each tank was then discharged. This resulted in a considerable amount of wastewater discharge. With the cascade rinse (as shown in Figure 3.10-1), the strip is sprayed with fresh water (or the cleanest water) as it leaves the final rinse tank. The rinse water collected in the final rinse tank is then cascaded (or pumped back) to the preceding rinse tank sprays. After it is sprayed to that portion of the strip, it falls into the rinse tank and from that tank the water is cascaded back to the preceding tank. This cascading action continues until the water reaches the first tank, which is the one following the pickling tank. The rinse water in the first tank, being the most highly contaminated, is then discharged for wastewater treatment, pickle tank makeup, deepwell disposal, or acid regeneration with the spent pickle liquor. The EPA reports that cascade systems can reduce rinse water discharge by approximately 90 percent.[1] Another reference indicates similar reductions and states that without cascade rinsing, water discharged from the rinse system could be as much as 200 to 550 gallons per ton of steel pickled compared with only 14 to 55 gallons per ton with cascade rinsing.[2]

Cascade rinsing is a form of recycling, in that the water is recycled from one tank to another; however, unlike other recirculation systems discussed in this study, the cascade rinse is not a closed-loop with a blowdown per se. Therefore, the dissolved solids buildup in the cascade rinse system does not pose the problems that other recirculation systems have. Because only one of the plants visited in this study had the cascade rinse, however, and its discharge was sent to disposal, this system will not be discussed further in this report.

Additional information on cascade rinse is available from a number of sources. Reference 3 provides a particularly good source.


STEEL STRIP
MAKE-UP WATER (11.5-12 GPM)
(600 GAL)
(575 GAL)
(550 GAL)
(525 GAL)
(500 GAL)
(475 GAL)
HCl PICKLING
(11.7 GPM)
SPENT PICKLE LIQUOR (6.5 GPM)
TO DEEP WELL DISPOSAL

PRODUCTION: ~960 TONS OF STEEL/TURN

Figure 3.10-1. Example of a cascade rinse system. (This particular system is employed on a continuous HCl pickling operation.)

Source: Reference 1.

REFERENCES FOR SECTION 3.10

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3.11 COOLING TOWERS

Using air as the medium, a cooling tower removes heat from water by evaporating water for the following reasons:

- To permit recirculation of plant water that has been elevated in temperature by its use in a process, equipment, condensing, or a combination of these to minimize water intake consumption in specific areas.
- To decrease the temperature of plant water to be discharged to a stream, river, or other body of water that would have detrimental effects on the aquatic balances in that stream, river, or other body of water.
- To meet existing local, state, or federal regulations governing intake water quantities (e.g., Section 316b of the Clean Water Act, which states: To minimize the quantities of water intake with a resultant destruction of fish, etc. at the plant's intake area may require the use of cooling towers to minimize the intake quantities required by the plant).

Cooling towers or ponds are used in the steel industry primarily on noncontact cooling water loops which are not covered in this study. They are also used, however, in blast furnace recycle systems and to a lesser extent in coke plant and rolling treatment systems. The use of cooling towers in contact water systems is much more complex than in straight noncontact cooling. This is due to evaporation and loss of water in the process and introduction of dissolved gases from the process. This section is intended only to introduce the fundamentals of cooling systems.

3.11.1 Cooling Techniques

Available cooling techniques include cooling ponds, spray ponds, wet natural draft cooling towers (counterflow or crossflow types), mechanical draft cooling towers, or a combination of wet and dry cooling systems.

Cooling Ponds--

Cooling ponds require large areas for the warm water to be cooled by the air coming in contact with the water surface area. The resultant cooled water can be discharged or reused. Evaporation rates are obviously a function of ambient temperature and humidity and are low compared with the rates for cooling towers.

Spray Ponds--

Spray ponds do not require as large an area as cooling ponds for the same degree of cooling. Heat transfer rate is enhanced by spraying the water into the air.

Cooling Towers--

The cooling tower permits evaporative cooling of the warm water when it is brought into contact with air. Cooling takes place when the latent heat is partially removed by the evaporation of some of the warm water and by transfer of sensible heat to the air; in essence, air is the heat exchange media.

Counterflow cooling towers--In the counterflow cooling tower (Figure 3.11-1), the air enters from the bottom through the fill area and passes up through the pumped warm water, which is at a higher temperature. The warm water then cascades or falls through the fill area to a collection basin below the incoming air; thus the air and warm water intermix, and the heated air and water mist continue upward for discharge to the atmosphere.

Crossflow cooling towers--In the crossflow cooling tower (Figure 3.11-2), the air enters from the sides through the fill area through which the warm water is cascading. The warm water and air mix at this point at a 90-degree angle to each other, and the heated air and water mist then enter the bottom of the tower and travel upward to the tower for discharge to the atmosphere, whereas the cooled water drops to the cold water basin below the fill area.

Natural-draft cooling towers--In the natural-draft cooling tower (Figure 3.11-3), air enters the bottom of the tower and contacts the water in either a cross-flow or counter-flow mode.

Mechanical-draft cooling towers--A mechanical-draft cooling tower induces an air flow through the warm water cascading through the fill by means of a fan or rotor located on top of the unit or by forced draft impellers located at the air inlet to the unit.

Dry Cooling--The dry cooling technique uses the same principle as the automobile radiator with a fan. It is not very efficient in the summertime because of the small $\Delta t^{o}F$ available.

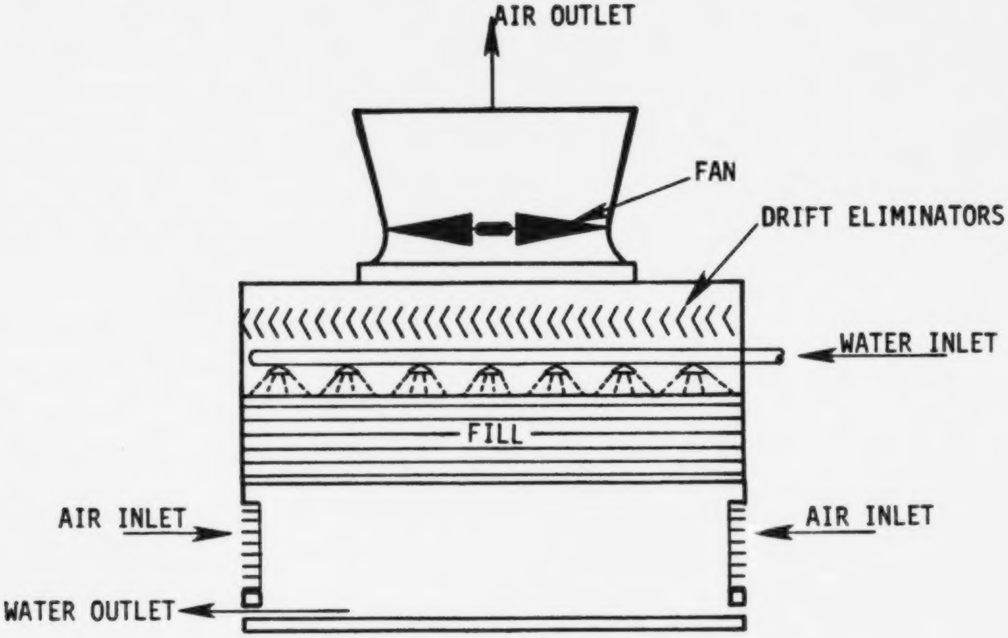
AIR OUTLET
FAN
DRIFT ELIMINATORS
WATER INLET
FILL
AIR INLET
AIR INLET
WATER OUTLET

Figure 3.11-1. Counterflow mechanical-draft cooling tower.

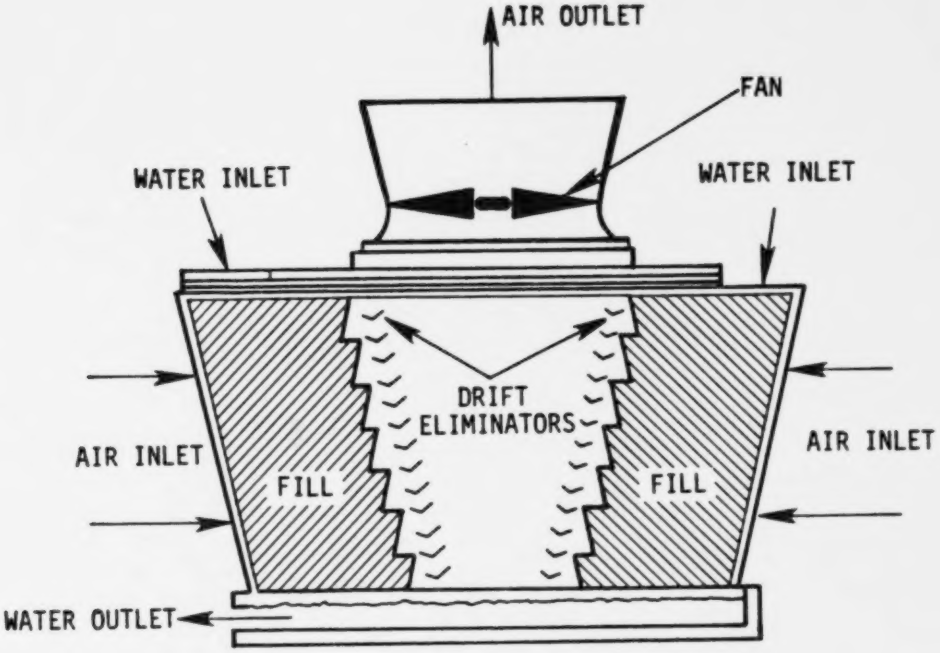
AIR OUTLET
FAN
WATER INLET
WATER INLET
DRIFT ELIMINATORS
AIR INLET
AIR INLET
FILL
FILL
WATER OUTLET

Figure 3.11-2. Crossflow mechanical-draft cooling tower.

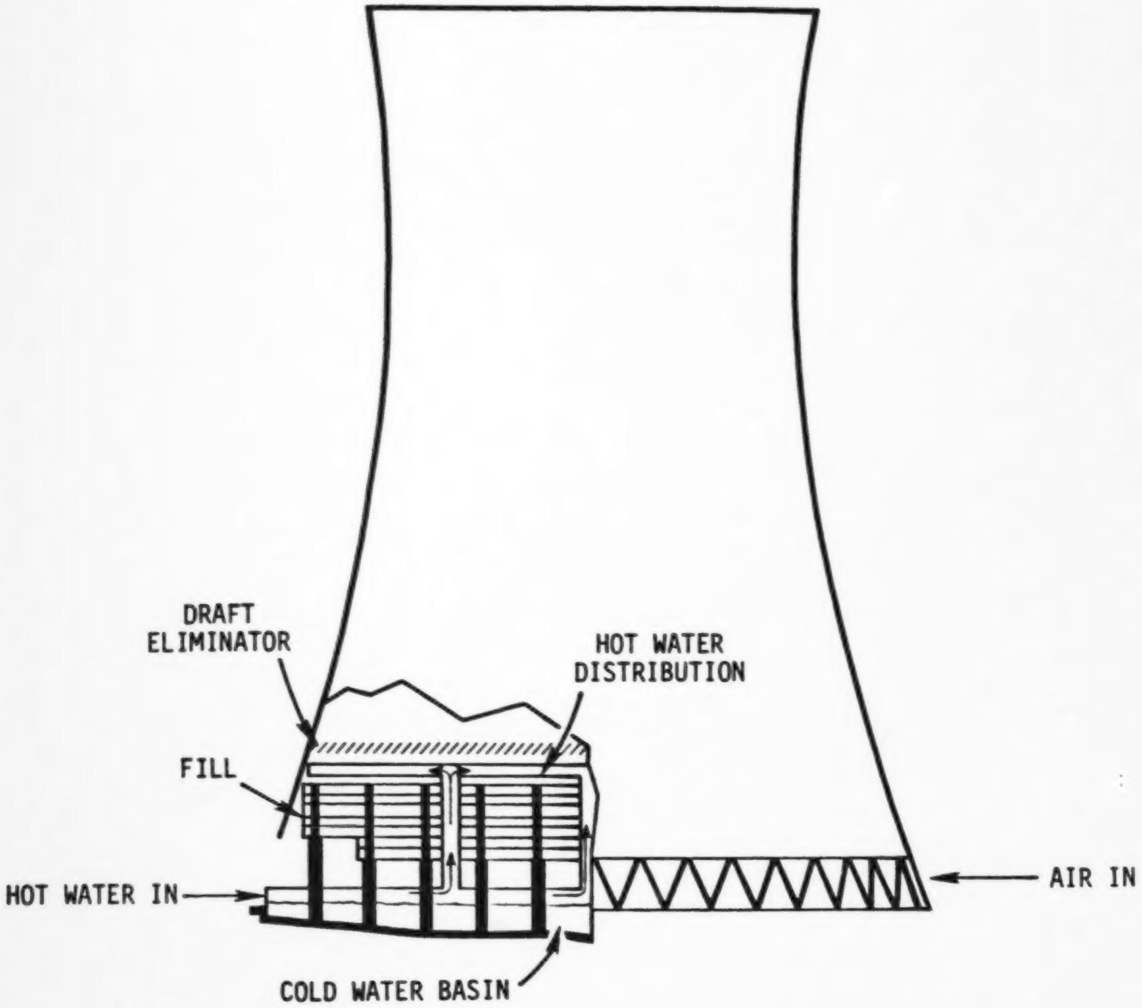
DRAFT ELIMINATOR
HOT WATER DISTRIBUTION
FILL
HOT WATER IN
AIR IN
COLD WATER BASIN

Figure 3.11-3. Natural-draft cooling tower.

3.11.2 Basic Design Parameters

The following constraints affect the design of cooling towers:

- Amount of land or land configuration
- Amount of water to be cooled
- Inlet temperature of the water
- Outlet temperature of the water either for reuse or discharge
- Wet bulb temperature
- Range of the system (the difference in temperature between the inlet temperature and the outlet temperature)
- Approach of the system (the difference between the outlet temperature and the wet bulb temperature of saturated air). This parameter has the greatest influence on the size and cost of the cooling tower.
- Heat load (the amount of heat to be dissipated by the cooling tower). This parameter, which is a function of the water circulation rate and the cooling range, also helps to determine the size and cost of the cooling tower.

3.11.3 Comparison of Cooling Tower Characteristics

Mechanical-Draft Cooling Towers--

Compact, less land requirements
Add-on ability
Low initial cost (investment)
Capable of low approach temperature
Less troublesome in winter operations
Air flow control

Natural-Draft Cooling Towers--

Minimal maintenance, few moving parts
Lower operating costs, no fan power
Less drift dispersion and noise
Maximum availability
No recirculation or interference due to height

3.11.4 Cooling Tower Performance

Because no natural-draft cooling towers were found in the course of this study, only those problems (and their causes) associated with mechanical-draft towers are discussed.

Frequent inspections and preventive maintenance are necessary for good performance of a cooling tower. The ability of a system to operate efficiently will decline as the result of wear and tear, misalignment of louvres, and erosion or corrosion.

The recirculation of water in a system with a cooling tower or pond causes dissolved solids buildup due to evaporation. Blowdown is required to discharge the dissolved solids loading. The amount of blowdown can be calculated theoretically by the formula:

$$B = \frac{E}{\text{Cycles} - 1}$$

where E = evaporation loss expressed as a percent of circulation rate

B = combined blowdown and windage loss expressed as a percent of circulation rate

Cycle = degree of concentration of dissolved solids in the recirculating water relative to the make-up water

Evaporation loss at the cooling tower is typically about 1 percent per 10°F temperature loss. In blast furnace and rolling mill systems, there is significant additional evaporation of water in the process. This is discussed more fully in Section 4. Windage loss typically falls in the following ranges:

Mechanical-draft towers:	0.1-0.3%
Natural-draft towers:	0.3-1.0%
Spray ponds:	1.0-5.0%

Figure 3.11-4 illustrates the relationship between cycles and makeup for various temperature drops across the cooling system.

Inspection Checklist--

The following checklist of items for inspection includes the exterior structure, distribution system (nozzles, valves, headers, etc.), spray system, interior structure (fill, etc.), mechanical equipment, and electrical equipment.

- Louvres -- Check for missing, rotted, or decayed louvres; maintain good air flow distribution
- Structural tightness -- Replace damaged or loose members; maintain good flow distribution

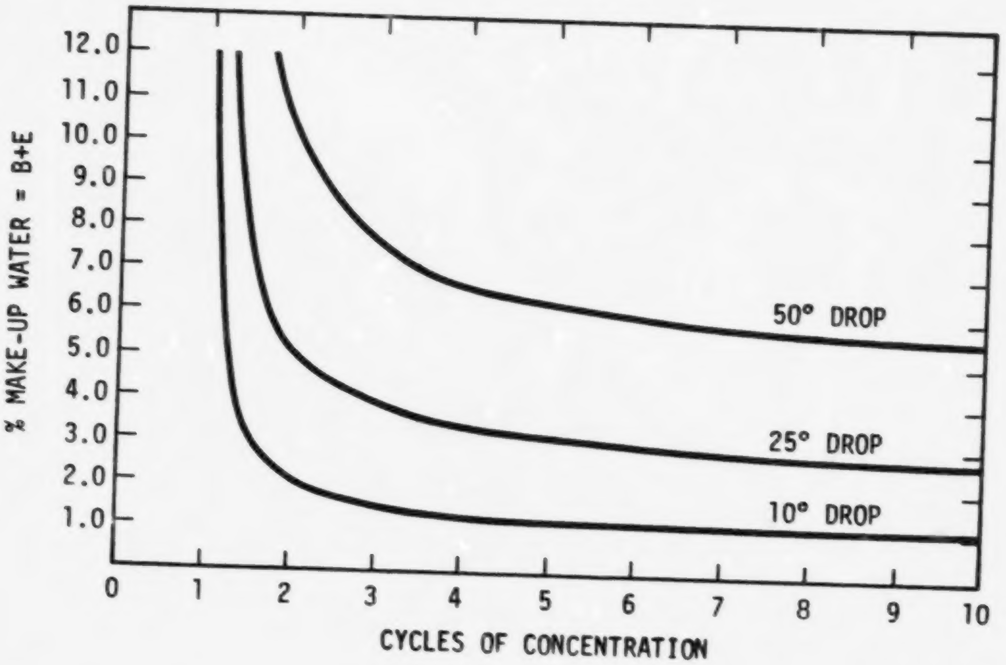

Figure 3.11-4. Makeup water requirements vs. cycles of concentration.

Courtesy of Betz Laboratories, Inc. Betz Handbook of Industrial Water Conditioning. Trevose, Pennsylvania, March 1973.

- Fan deck -- Check for decay, missing or damaged members -- Can cause short-circuiting of air flow
- Distribution system -- Check headers and supports (rust, decayed or acidic actions), nozzles (clogged), basin redistribution system (for cooling and flows)
- Mechanical equipment supports -- Check for corrosion, decay, or rust
- Drift eliminators -- Check for decay, broken or missing members, misalignment, algae, debris, or slime (excessive drift can occur)
- Fill -- Check for deteriorated or missing fill, collapse from ice damage (will affect range and approach)
- Structural internal supports -- Check for soundness (could cause a collapse of the system)
- Mechanical equipment -- Check for corrosion, erosion, buildup, tightness, oil condition, bearing play, and vibration
- Electrical -- Check motor, bearing lubrication, vibration
- Cooling water treatment system and recirculation systems -- Check makeup and blowdown rates; calculate cycles (to minimize corrosion, deposits, and slime)

Factors Affecting Corrosion, Deposits, and Slime--

- Factors influencing scale formation are pH, alkalinity, calcium, and other dissolved solids.
- Factors influencing fungus growth are pH, warm weather, humidity, and absence of light. Fungus attacks wood and causes rot. The solution is to replace the wood with transite or plastics, or to treat the wood prior to installing.
- Factor influencing slime growth is low pH. Slime causes corrosion and lowers heat transfer.
- Scaling results from the deposition of material normally in solution, whereas fouling results from deposition of material normally in suspension.

These factors are controlled by a bleed stream or blowdown, by coagulation and filtering, or by the addition of inhibitors and chemicals that attack the specific problems. These include dispersants, fungicides, and slimicides. Proper control of chemical additions is important both for performance and because fungicides and slimicides are toxic chemicals.

3.12 AMMONIA STILLS

A weak ammonia solution is produced in the collecting mains of coke ovens when water is sprayed on the hot gases leaving the ovens. The ammonia concentration varies, but it can range from 700 to 2000 ppm of free ammonia and 1000 to 3000 ppm of fixed ammonia.[1] This ammonia is generally reduced to less than 150 ppm in ammonia stills.

3.12.1 Equipment Description

The free ammonia in the water can be easily steam-stripped, but the fixed ammonia is in the form of ammonium salts and must be treated with a base to free the ammonia.

Figure 3.12-1 presents an example representing one of several stripping equipment arrangements used. The ammonia solution is introduced at the top of the column while steam is injected into the bottom. In the example shown, the column has 17 trays, and free ammonia is stripped out on the top 4 trays. The ammonia solution leaves the column from the 14th tray and enters a mix tank. Lime is added, and steam is sparged into the tank to promote mixing. The retention time here is about 15 minutes.

From the mix tank the slurry flows by gravity to a Lamella® clarifier. The clarified solution flows from the clarifier to a small pumping tank and is then returned to the 13th tray. The pH at this point is about 10.5, which is high enough to liberate most of the fixed ammonia. As the solution flows across the trays to the bottom of the column, the steam strips out most of the remaining ammonia. The column bottoms are then pumped to a waste liquor holding tank. From there the solution can go to a biological treatment plant.

A Lamella® clarifier was chosen for this installation because it requires very little space. The clarifier's internals are composed of plates set on an incline. The sludge settles out on the bottom of these plates as the liquid flows through the clarifier.

A little over half of the North American steel plants now use some form of ammonia distillation in the treatment of flushing liquor. About half of those plants with ammonia stills recover fixed ammonia by elevating the pH of the water with lime or caustic soda.[2] Some plants do not prestrip the free ammonia and lime the water before it enters the stripping column.

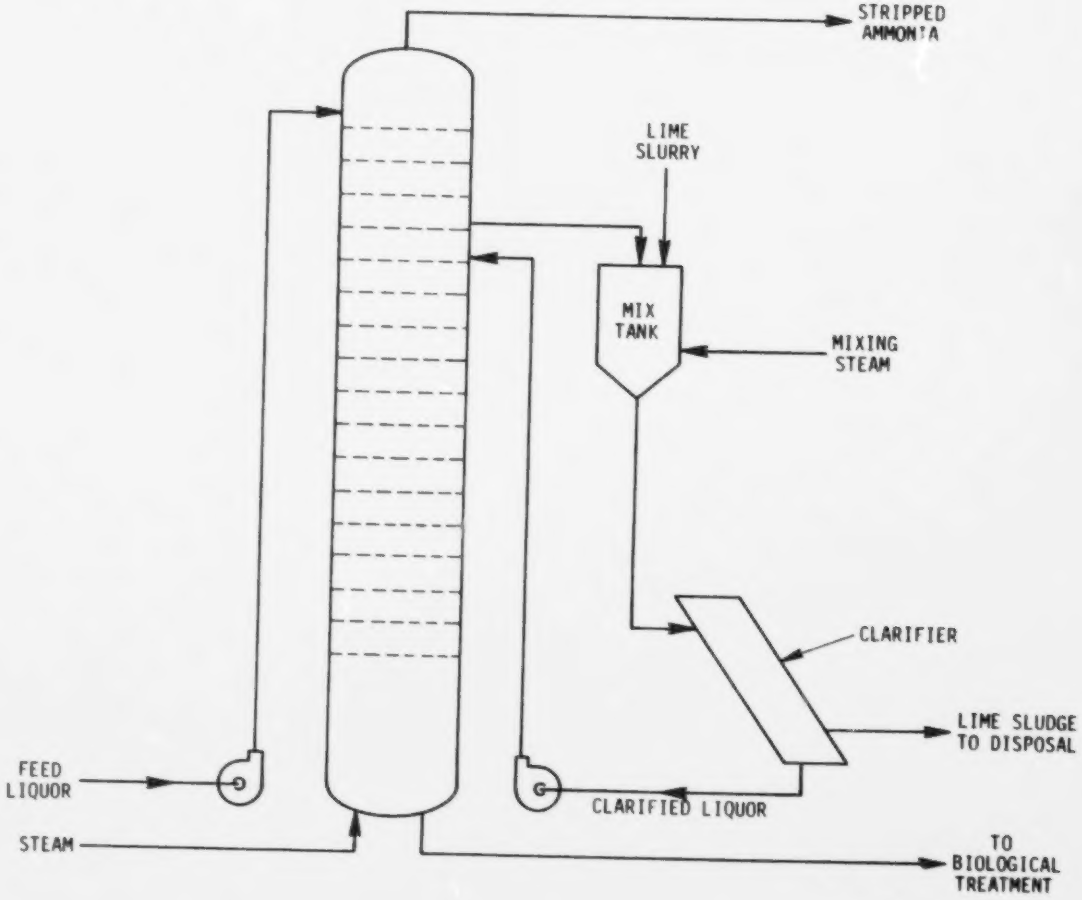
STRIPPED AMMONIA
LIME SLURRY
MIX TANK
MIXING STEAM
CLARIFIER
LIME SLUDGE TO DISPOSAL
FEED LIQUOR
CLARIFIED LIQUOR
STEAM
TO BIOLOGICAL TREATMENT

Figure 3.12-1. An example of an ammonia stripping system.

Other systems do not have a clarifier, and the lime goes directly into the column. In this case, the column must be acid-washed fairly frequently.

Any arrangement entailing the use of lime must be designed to cope with fouling. An access port is usually provided at each tray, and the trays themselves must be designed for easy disassembly and cleaning. Figure 3.12-2 shows an example of a tray design and one stripping column. The caps on the tray can be removed through the access port, which allows every part of the tray to be reached for cleaning. The design should also include provisions for acid flushing the entire column.

Fouling problems could be greatly reduced by the use of sodium hydroxide instead of lime, but this could increase the operating cost by a factor of 7.[1] One mill installed a caustic tank and operated on caustic for a trial period to make a thorough study of the economics. Even with the reduction in maintenance and sludge disposal cost, the use of caustic proved to be much too expensive.

Although crushed lime could be added directly to the column, slaked lime is preferable. Slaking is the process of mixing quicklime (CAO) with water to produce a lime slurry suspension of calcium hydroxide.

$$CAO + H_2O \rightarrow CA(OH)_2 + \text{heat}$$

A lime slaker mixes the proper amounts of quicklime and water under the proper temperature and agitation conditions to disperse the hydrated particles as they form. This slurry is then transferred to a dilution tank, where additional water is added. The plant should maintain enough slaked lime storage to provide for breakdowns in the slaker, and surge should be provided for the column feed solution to allow for column and slaker outages.

3.12.2 Governing Design Parameters

Temperature is important in the slaking operation. If the temperature is too low, the calcium hydroxide being produced will adhere to quicklime particles instead of being dispersed. This in turn prevents the quicklime particles from reacting. At the other extreme, excessive heat causes "burning" or localized overheating at the surface of the quicklime particles. This overheating causes unreactive oxide and hydrate crystals to form. Burning usually produces steam which removes water, producing even higher temperatures.

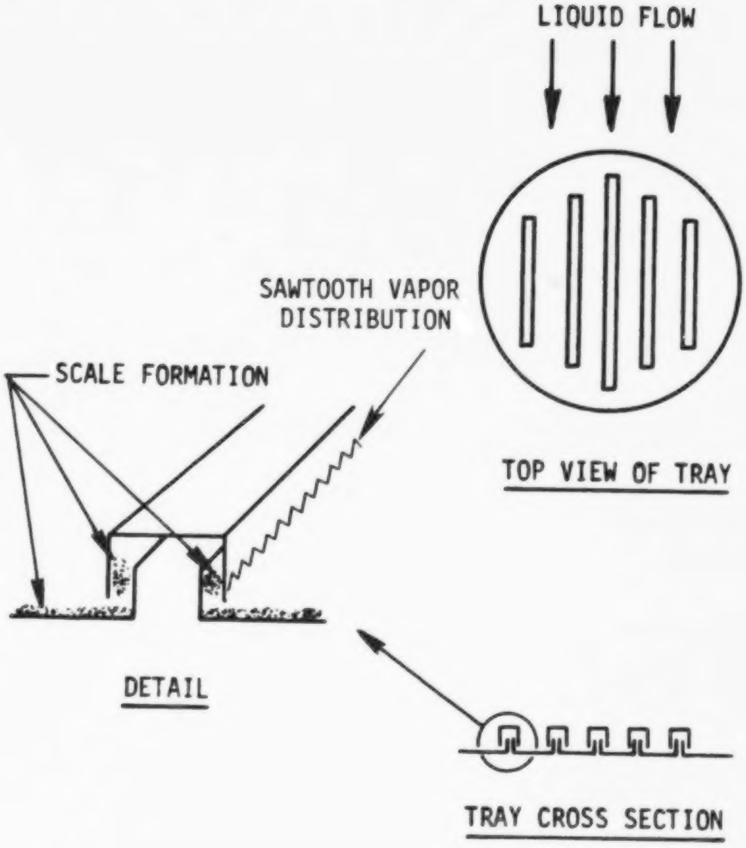
LIQUID FLOW
SAWTOOTH VAPOR DISTRIBUTION
SCALE FORMATION
TOP VIEW OF TRAY
DETAIL
TRAY CROSS SECTION

Figure 3.12-2. An example of a tray used in an ammonia stripping column.

If not controlled, the overheating can damage the equipment. One plant maintains a temperature of 95°C. Water is added to the slaker as necessary to maintain this temperature. Also, a temperature test is used to evaluate the quality of the lime shipments. This entails mixing a measured amount of lime and water and recording the maximum temperature. This permits the plant to determine the calcium oxide content of the lime.

The particle size of the lime also must be controlled for good slaker operation. A typical specification calls for 80 percent of the lime to pass through a 1/4-inch screen.

Control of the pH is very important during the addition of the lime. The pH should be as high as possible to maximize the release of ammonia, but the maximum pH at which the lime will dissolve is about 11. When this value is reached, any additional lime does not dissolve, but will simply increase the suspended solids level in the liquid. One reference reports that at a pH of 10.9 and a temperature of 90°C, more than 99.9 percent of the ammonia is in the free state.[2] The reference further states that this condition is readily achieved with lime. The plant that had actually used sodium hydroxide on a trial basis, however, said that removal was much easier with sodium hydroxide. They indicated that although they could produce a column effluent with about 100 ppm of ammonia by using lime, the level could easily be dropped to 10 ppm by using sodium hydroxide.

The pressure drop in the ammonia column is monitored by use of a pressure gauge at the bottom of the column. As the column plugs, the pressure drop across the column will increase. Since pressure drop depends on the column design as well as the liquid and gas flow rate, the absolute value of the pressure drop depends on the individual system.

Steam injection rate is very important. Most conventional stills use 2 to 3 pounds of steam per gallon of ammonia liquor.[2] Using too much steam is a waste of money, whereas using insufficient steam will result in poor ammonia removal.

3.12.3 Operation and Maintenance Problems and Solutions

Most stripping system problems involve handling the lime. Incoming lime shipments should be checked to make sure the calcium oxide content and particle size are within the correct range. When the lime is added to the ammonia solution, the operator must add sufficient lime slurry to release the ammonia but not so much as to create excessive suspended solids in the liquor.

The lime tends to foul and plug pipes, control valves, instrumentation, and the stripping column itself. A preventive maintenance schedule should be set up to break apart and clean the equipment before it becomes inoperable. Also, storage of slaked lime or diluted lime slurry (i.e., ammonia still feed) should be maintained for slaker outages.

Figure 3.12-2 shows the points at which one type of tray will scale up during column operation. In this particular tray design the caps can be removed and pulled out through the manways on the stripping columns above each tray. Periodically, the caps are removed and the trays and caps are water-blasted. The operator should keep a continuous watch on the pressure drop across the column as an indicator of when the trays have become fouled and require cleaning.

Solids can settle out of the waste liquor after it leaves the ammonia column. One plant had installed a large storage tank to receive the ammonia column water discharge. The liquid from this surge tank is pumped to the biological waste treatment system. Initially, the pump suction line came from the bottom of the surge tank, but so much sludge settled out in the tank that the pump would not operate reliably. The tank was then repiped as an overflow type, and the liquid flowed by gravity from the top of the tank to the biological waste treatment system. A vacuum truck was used to remove sludge from the bottom of the tank via the old pump suction line. About 180 tons per month of lime sludge is now removed from the tank.

At one plant the carbon steel plates in the Lamella® clarifier corroded away after the unit was installed, and the plant replaced them with stainless steel plates. These have held up well.

Plant operators monitor the pressure in the bottom of an ammonia still. When the pressure reaches the established upper limit, the operator knows that it is time to take the column off line and clean it. The column feed tank should always be run at a low level to allow a place for surging the ammonia solution if the column goes down for repair.

Control of pH is based on adding lime at a rate proportional to the influent ammonia solution flow rate. The pH of the incoming liquor is monitored, and the proportion of lime to liquor is a function of influent pH. Cleaning the pH probe should be included in a preventive maintenance schedule, and an operator should manually check the pH as often as required.

Steam flow is critical to efficient still operation. The flow should be adjusted to maintain the proper ratio with the feed liquor flow. Inadequate steam flow will lower the column efficiency dramatically.

The still's ammonia product typically goes either to a plant where ammonia is produced or to an incinerator. One plant operated an incinerator until economics compelled them to put in an ammonia recovery unit. That plant has maintained the incinerator for use as a backup if the ammonia plant should go down.

The water going to the ammonia stills comes from moisture in the coking coals. During periods of high humidity and rainfall, the amount of moisture in the coal and the resulting water flow to the ammonia columns increase noticeably. Because of these variations in flow, close attention must be given to the level in the ammonia column feed tank, even during periods when coke plant production is relatively constant.

REFERENCES FOR SECTION 3.12

1. Glassman, D. USS CYAM System, an Improved Process for Ammonia and Cyanide Removal from Coke-Plant Wastewater. Ironmaking Conference, Vol. 35, St. Louis, Missouri. March 1976.

2. U.S. Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category. Volume II. EPA 440/1-80/024-b, December 1980.

SECTION 4

WASTEWATER CONTROL SYSTEMS

This section describes several of the major classes of treatment systems utilized at the plants visited during the study. Because specific details of treatment systems, and in some cases major components, vary widely from plant to plant, this section is largely limited to the operation and maintenance practices at the plants visited. Information has been taken from past studies and from the literature to supplement the specific plant experience. In general, however, the literature contains very little information on detailed O&M practices.

4.1 COKEMAKING

The iron and steel industry uses various treatment systems and component arrangements for treating coke plant wastewaters. Most plants have installed specifically designed removal equipment for two pollutants--ammonia and phenol.

About two-thirds of the plants with cokemaking facilities have ammonia stills (described earlier in Section 3.12). All of these plants have free ammonia stills, and approximately 85 percent of them also have fixed ammonia stills.

About two-thirds of all plants with cokemaking facilities also have treatment systems for removing phenol. About half of these plants have dephenolizers and the other half have oxidation systems, primarily bio-oxidation. Because the coke plants visited have free and fixed ammonia stills with subsequent biological treatment, and because these treatment technologies are common in the iron and steel industry, the following subsections address these systems.

4.1.1 Arrangement of Treatment Components

Various types of wastewater treatment systems and arrangements of components are used for treating coke plant wastewater. Many of these variations are shown in Reference 1. Configurations of two of the systems visited are illustrated in Figures 4.1-1 and 4.1-2. Their overall arrangements are similar. The main differences are that the system in Figure 4.1-1 has a clarifier preceding the aeration basins (primarily to remove coal fines from one of the inlet wastewater streams) and an emergency lagoon.

4.1.2 Identification of Major Areas of O&M Concern

The following are the major areas of O&M concern for coke plant biological systems because failure to properly operate, maintain, and monitor them could result in loss of the treatment system.

- Performance of the ammonia stills
- Control of basin pH
- Control of basin temperature
- Nutrient addition
- Aeration

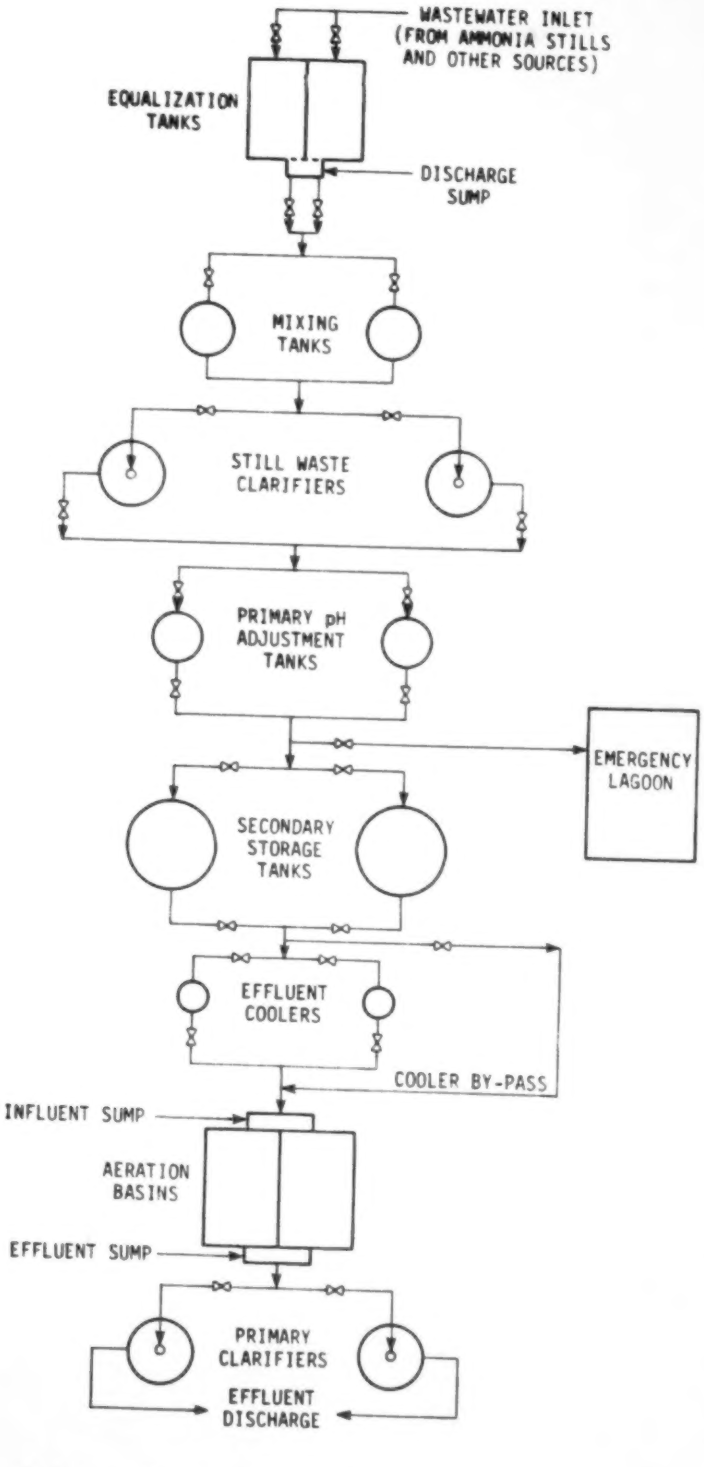
WASTEWATER INLET
(FROM AMMONIA STILLS
AND OTHER SOURCES)
EQUALIZATION
TANKS
DISCHARGE
SUMP
MIXING
TANKS
STILL WASTE
CLARIFIERS
PRIMARY pH
ADJUSTMENT
TANKS
EMERGENCY
LAGOON
SECONDARY
STORAGE
TANKS
EFFLUENT
COOLERS
COOLER BY-PASS
INFLUENT SUMP
AERATION
BASINS
EFFLUENT SUMP
PRIMARY
CLARIFIERS
EFFLUENT
DISCHARGE

Figure 4.1-1. Flow diagram of plant visited.

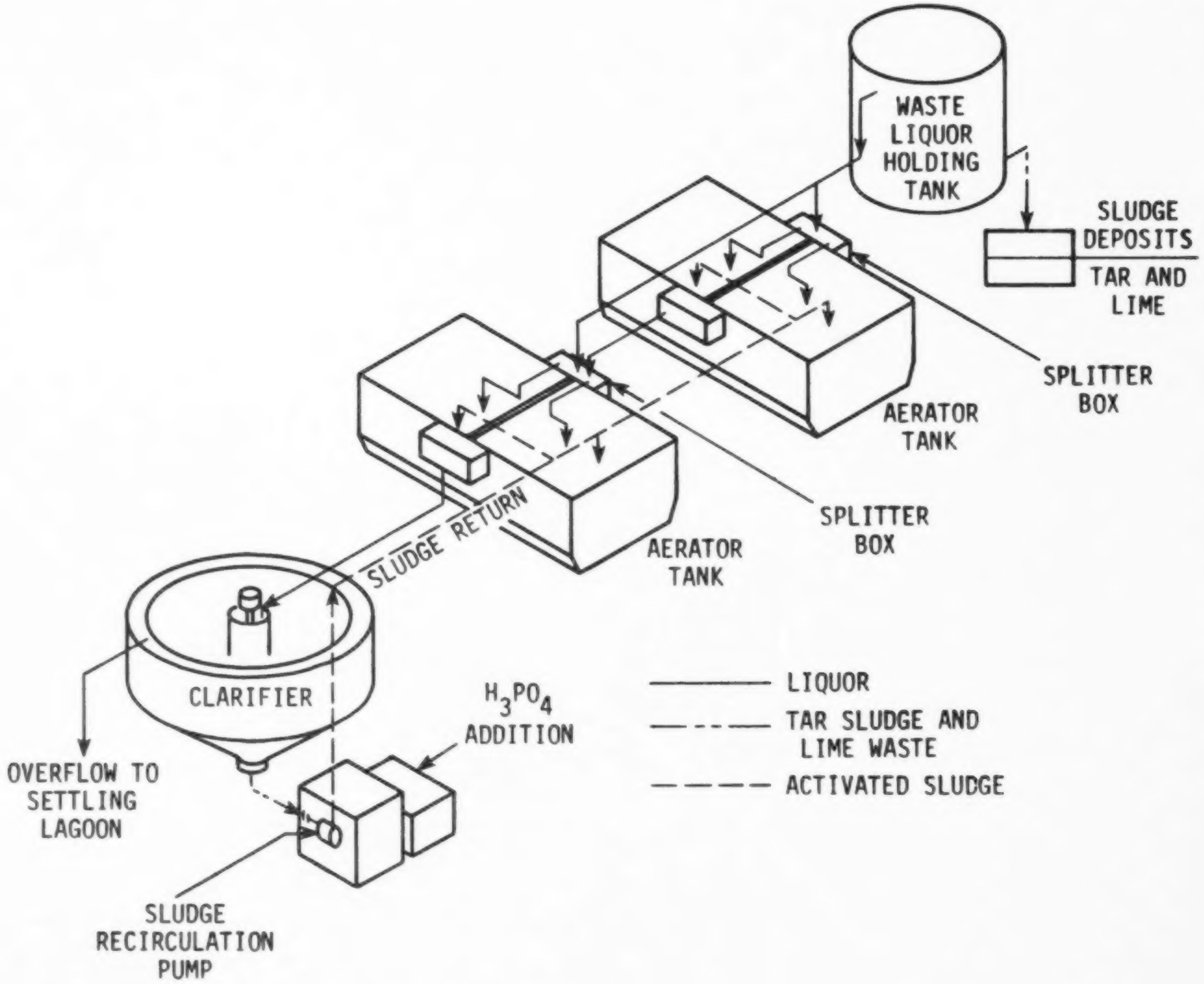
WASTE LIQUOR HOLDING TANK
SLUDGE DEPOSITS
TAR AND LIME
SPLITTER BOX
AERATOR TANK
SPLITTER BOX
AERATOR TANK
SLUDGE RETURN
CLARIFIER
H_3PO_4 ADDITION
OVERFLOW TO SETTLING LAGOON
SLUDGE RECIRCULATION PUMP
LIQUOR
TAR SLUDGE AND LIME WASTE
ACTIVATED SLUDGE

Figure 4.1-2. Biological plant flow diagram.

- Maintenance of adequate dilution water
- Introduction of intermittent, experimental, or toxic material
- Monitoring of key parameters
- Communication
- Operator attention and know-how with good supervisors

Ammonia Still Performance--

Poor ammonia still/lime (or caustic) handling operations can result in adverse still effluent levels of ammonia, lime, pH, temperature, and flow. Therefore, proper operation and maintenance of the ammonia stills is critical to the performance of the biological plant. Because effluent from the stills usually comprises the largest input to a biological plant, any sudden changes in still performance that changes the composition of its effluent can adversely affect biological activity. The extent of the effect depends on the nature of the still's performance problem, the duration of the problem, the equalization basin capacity, communication of the problem to the treatment system operators, and operators' experience and effectiveness in dealing with the problem.

Control of Biological Basin pH--

The pH of the wastewater in the aeration basins should be maintained between 7 and 7.8 for optimum phenol oxidation and thiocyanate removal (denitrification). The pH is affected by the pH level of the ammonia still effluent; the pH of other influent streams (e.g., from the light oil plant); dilution; and whether acid neutralization (e.g., the use of sulfuric acid) is practiced, and if so, the degree of control.

Control of Basin Temperature--

The plants visited report that maintenance of the aeration basin temperature at approximately 25° to 30°C allows optimum biological activity. This agrees well with the literature.[1,2] One plant reported that the microorganisms will be pasteurized at 40°C. Because the optimum basin temperature has such a small range (≅5°C), the importance of temperature control cannot be overemphasized. The basin temperature depends on the still effluent temperature, the retention time from still outlet to basin inlet, the ambient temperature, and the equipment used for temperature control at the biological plant (e.g., heat exchangers, small cooling towers, steam spargers).

Nutrient Addition--

Most coke plant biological systems require more nutrients than those present in the wastewater feed. Generally, phosphoric acid is added to supply this need. An adequate amount of nutrient must be added to prevent the microorganisms from dying.

Aeration--

The aeration basins (typically called the bug plant or bug ponds) must have a continuous and uniform supply of oxygen (air) to provide the concentrations needed for the good health of the microorganisms (bugs). The plants visited maintained minimum dissolved oxygen concentrations of 1 to 2 ppm.

Dilution Water--

Dilution water is often added to biological systems at coke plants to aid in reducing the concentrations of influent feed to a level acceptable to the bugs. One of the plants visited added approximately as much dilution water as the amount of the inlet flow; another used dilution for cooling in hot weather and for maintaining the thiocyanate concentration of the basin inlet stream to less than 300 ppm. One plant, which recently started up, was designed to operate without dilution water. (This plant was expected to experiment with powdered activated carbon to aid in system stability; this should also help to reduce foaming.)

At those plants depending on and designed for the addition of dilution water, the availability and control of this water is important in maintaining a healthy bug population.

Introduction of Intermittent, Experimental, or Toxic Material--

Microorganisms, like other living things, thrive on a properly controlled, consistent diet and environment. The addition of intermittent and experimental wastes (those that can be biologically degraded) to a biological treatment system is permissible if practiced in moderation, if concentrations are low, and if operators are knowledgeable regarding possible effects of such additions on the system and its effluent quality.

Materials other than normally treated wastewaters that could have a toxic effect on the bugs (e.g., chromate, chromium, copper, lead, nickel, and zinc) should not be introduced to the treatment system. Also, brass fittings, copper tubing, galvanized steel, etc., should not be used or lost in the system.

One plant reported that sulfide concentrations of approximately 75 ppm can reduce system phenol removal by 80 percent. They further indicated that spills of Stretford liquor or hydrogen cyanide liquor must be isolated and not be allowed to get into the treatment system.

Monitoring of Key Parameters--

To know that a treatment system is performing properly, the operator must closely monitor key parameters of the treatment components that make up the system. In this text, monitoring includes physical observations of equipment (e.g., basins, clarifiers) to check things such as waste color, settling behavior, foaming, odor, unusual noises (e.g., in pump houses), water levels, and movement of chemical additives. Monitoring also includes taking periodic water samples and analyzing for key chemical parameters (e.g., pH, ammonia, phenol, thiocyanate, and suspended solids in the feed liquor to the basins or measuring MLVSS), and inspections of instrumentation readings such as temperatures, flows, pH's levels, and amperages. This monitoring can be done from a central control room (if one exists), from individual stations, or from a computer terminal. Two of the plants visited had computerized data systems with key operating data available at conveniently located terminals. No matter how sophisticated a control panel and instrumentation system are, however, these systems can be faulty as a result of plugging of detection equipment, miscalibration (or no calibration) etc. Therefore, the best backup for reliability is for a good operator to walk through a system periodically and check things firsthand.

The practice and frequency of monitoring are vital to the successful operation of a treatment system.

Communication--

Good communication must be established among all personnel whose actions affect the treatment system. The lack of such communication can result in system upsets, additional cost to correct a problem, and sometimes in equipment damage. Specifics are discussed in Section 6. For coke plant systems, however, one can easily see the importance of communication between the ammonia still operator (usually in the byproducts process group) and the biological plant operator (usually in the utilities department) if, for example, the ammonia stills become plugged or lose steam causing high ammonia water to enter the treatment system. In this case, the importance of good communication between the process operator, his supervisor, and the maintenance department is also apparent.

Good communication relies on establishing a quick method of contacting the necessary people (e.g., telephone, beeper); on such intangibles as having mutual trust (so that the involved parties can believe each other); and on having a reasonable understanding of each other's system (so discussions can be more knowledgeable).

Operations and Maintenance Personnel Know-how--

Obviously, the people who are responsible for a given system should know how to operate and maintain it (assuming that system is fairly well designed). Operator know-how should not be underestimated though. Observations made at the several plants visited indicated that there is no substitute for a well-trained, conscientious operator. After the regulations are issued by EPA, state and plant environmental personnel negotiate for months regarding a permit, plant management considers control alternatives and economics, engineering and instrumentation teams design the systems, and companies build and start up multimillion dollar facilities. In the long run, however, the success of these facilities depends on the expertise of one, two, or three operators at a given time (who most likely had nothing to do with any of the former decisions). Their know-how (learned through training and experience) and conscientiousness are vital to proper system operation and to bringing their systems back after upsets. Therefore, the selection of good personnel to operate these systems is a major concern.

4.1.3 Identification of Effective O&M Practices

The effective practices discussed here under each area of concern are primarily those observed at the visited plants. When applicable, the literature is also cited. When practices differ from plant to plant, the various alternatives are presented.

Ammonia Still--

Because the operation of ammonia stills greatly affects a biological system, this operation is discussed step by step. This section focuses on lime stills rather than caustic stills because of the increased operational and maintenance difficulty associated with the former. Beginning at the front of the system, the following effective O&M practices were observed.

Crude liquor flow--Flushing liquor from the coke batteries to the byproducts (ammonia still) recovery area requires an adequately sized storage tank. One plant had an approximately 400,000-gallon tank (≅20 hours detention), which it kept about a third full. The practice of maintaining this level (e.g., one plant recorded the level every two hours) allowed the batteries to continue operating without interruption during still shutdowns. This level was also adequate to provide a source of constant flow to the stills.

Return liquor flow--The plants frequently monitor the flows from the lime legs back to the stills. This allows adjustments to be made to the steam flow as needed and makes it possible for the still operator to balance flows between stills if more than one is in operation. One plant monitored and recorded the flow rate every two hours.

Steam flows--Proper adjustment of the steam flow to the lime leg discharge is necessary to supply an adequate amount of steam to strip the ammonia from the liquor. To make proper adjustments, the still operator must know what the liquor return flow is and how much steam is required per unit of flow. Operators at one plant use an easily read chart showing proper steam/return liquor flow ratios. The normal ratio at the plant is approximately 1.5 lb of 15 psig steam per gallon of liquor treated (~180 gpm at ~2000 ppm fixed ammonia). The operator said that maintenance of the proper ratio is important because a steam rate lower than that required causes the stripping column efficiency to drop off very rapidly.

Still Pressure--

Still pressure should be monitored regularly. The plant cited above also does this bihourly. The operators monitor and maintain a working still pressure of 3 to 5 psig. Besides assisting the operator in the maintenance of proper pressure for good column performance, the monitoring and recording allows the operator to see indications of pressure rises, which usually indicate blockage in the still or lime leg. Noting these changes and calling them to the attention of the maintenance department comprise an effective operating practice.

Lime Slaker Operation--

Lime storage--The level in the storage bin or tank should be checked periodically. Operators at one plant checked and recorded the relative level at the beginning of each shift and reported low levels to the foreman in charge.

Slaker feed water control--Feed to the slaker should be of relatively uniform size and maintained at a steady rate. The lime/water ratio should be maintained to give the proper consistency to the lime paste. Consistency and temperature of the mix can be controlled by adjusting the water valve. The lime mixing spray should be inspected for blockages. Quality control of the slaking operation permits a more consistent lime feed to the fixed leg of the still and improves still operations. Also, close control of lime quality (periodically testing the calcium oxide content of the purchased lime), lime size as received (approximately 80 percent less than 1/4 inch), and lime slurry temperature (90° to 95°C) has improved the dissolution of lime into the slaker water and has reduced lime consumption considerably over what it was when no quality control (an effective operating practice) was practiced. The quantity of lime sludge that forms in the treated ammonia liquor tank has been cut approximately in half, as evidenced by the decreased number of vacuum truck haulings.

pH control--Plants often use a pH controller on the still effluent to control the amount of lime water being fed to the lime legs for reaction with the crude liquor. Low still effluent pH (e.g., below 9.3) means that not enough lime is being added to the system. High pH (e.g., above 9.8) means that too much lime is being added to the system which, will produce good ammonia removal, but will also cause too high a solids concentration. Because of inherent plugging problems, a pH controller with pH probes cannot be depended on in a lime-based system. Therefore, effective O&M practices are required to back up (or substitute for) pH control. Besides monitoring the pH meter, operators at one plant also checked the pH of the effluent and of the liquor from the lime leg going to a Lamella® separator every two hours. The normal operating pH of the lime leg discharge is from 9.9 to 10.4. The operators said that by checking the pH of the still bottoms every two hours and adjusting the return set point, they could achieve effective pH control.

Ammonia still/slaker--Other effective O&M practices observed at the plants included frequent inspections of all operating equipment (e.g., pumps, motors, valves, and controlling equipment). Any malfunctioning equipment was reported to the area foreman and noted on the log sheets.

Preventive Maintenance--

The question frequently arises whether preventive maintenance (P-M) is worth the effort. Because of the number of "fires" that have to be put out, maintenance people do not have enough time to practice preventive maintenance. It is usually a management decision based on experience and philosophy. That effective operation depends partially on the considerations and implementation of a P-M plan was obvious in the review of long-term data of the performance of lime stills at a plant before and after a P-M program was put into effect. This was also apparent from discussions of the program with the operating supervisors. (An example is given in Section 6.4.) This effective practice of performing P-M (e.g., cleaning still trays at planned intervals) has decreased still downtime, increased reliability and performance, and drastically reduced the number of permit excursions.

During bad economic times, the tendency is to reduce the P-M effort in the belief that money should be spent only when something breaks down. Discussions with people responsible for maintenance budgeting (those who have kept good records and accounting of maintenance costs vs. P-M costs) have indicated that many find P-M is more cost-effective in the long run.

Biological Treatment Systems--

Well-designed biological treatment systems effectively reduce the target pollutants if they are operated and maintained properly. Effective O&M practices observed for these systems are described here.

Control of aeration basin pH--The aeration basin pH must be maintained at an optimum range (e.g., 7 to 7.8) for maximum removal of phenol and thiocyanate (and other organic compounds). Maintaining the pH in the optimum range will also prevent a bug kill from high pH shock. One plant visited had initially designed and installed pH adjustment tanks with a sulfuric acid feed control system to neutralize the wastewater from the equalization tanks. Content of the tanks was mainly ammonia still effluent, and the equalized stream had an average pH of approximately 9. The pH adjustment system was used for a while, but close monitoring of pH at various points showed that the pH adjustment was not required because the addition of dilution water in the aeration basin influent sump and the bio-oxidation reactions (liberation of carbon dioxide may partially form a weak acid) apparently had a neutralizing effect on the pH. The pH of the basin influent, which usually is approximately 9, is reduced to about 7 in the basin effluent by the addition of sulfuric acid. A similar reduction occurred at another system visited. Both systems are well operated and maintained and have good mixing and healthy bug populations. The "biological" reduction of the pH would seem to occur only when the systems are healthy and oxidation of organics occurs at a high rate.

The most effective operational practice observed at different biological treatment systems is to monitor the basin pH and its sources. At one plant, operators take samples from the equalization tank effluent, influent to secondary storage tanks (each with a million-gallon capacity), effluent from these tanks, basin inlet sump, and basin outlet sump. The samples are taken every 4 hours, and the pH's are analyzed and recorded on a daily log sheet. At another plant, wastewater treatment operators, who are also responsible for the ammonia stills, take bihourly wastewater samples from the ammonia stills and daily samples of the basin wastewater feed and clarifier overflow. These samples also are analyzed for pH and recorded.

These frequent sampling and monitoring practices permit early detection of deviations to the normal pH range, and corrective action can be implemented immediately to protect the system and effluent quality (e.g., diversion to an emergency storage tank, if necessary). It should be noted that pH meters need frequent calibration. One plant calibrated them daily at the least.

Control of basin temperature--Microorganism activity diminishes if wastewater becomes too cold, and microorganisms can be killed if wastewater temperatures are too high. The optimum temperature range for coke plant biological systems is about 25° to 33°C. To achieve this narrow range, three of the plants visited have well-designed equipment with temperature controls to heat or cool the wastewater as needed. One plant cools their wastewater with two spiral-type coolers and heated the water with a steam sparger in the basin influent sump. The desired cooling water temperature is set on a controller and the temperature is monitored by a recorder on a wastewater control panel. For heating, the volume of steam to the sparger is monitored by a flow recorder (with an integrator). The basin influent sump has two temperature elements connected to a pen recorder on the control panel.

Another plant cools the water by evaporation and by using the still waste liquor coolers. Heating is accomplished with direct steam lances. (This plant said that another facility close by used steam above the water to maintain a "heat blanket" because they believe live steam injection into the water will scald a portion of the bugs.) The third plant, which has the newest biological system, uses three heat exchangers (one is a spare) for cooling and a 1000-kilowatt hot water heater for heating. Temperatures are continuously monitored and recorded at the control room.

Even though the plants are equipped with monitors, control valves, and recorders on control panels, the operators still make their rounds and record temperatures at the source. For example, one plant records and logs temperatures bihourly at the still effluent aeration basin inlet and at the four aeration cells. The monitoring and control equipment coupled with the operators' inspections/logging have resulted in excellent temperature control.

Nutrient addition--All of the systems visited use phosphoric acid as nutrient. At one plant, the inlet concentration was 4 ppm (75% concentration) and there was a 1 ppm phosphate residual in the basin. (The temperature of the acid is maintained at a minimum 10°C by electric heaters.) Another plant also maintains a 1 ppm phosphate residual in the basin. The operators adjust a valve to the required dosage rate. They also monitor usage of the nutrient and report that approximately 20 gallons per day of phosphoric acid (63%) are needed. (The wastewater flow is approximately 200 gal/min.)

At both plants, the operators regulate the phosphoric acid addition. At one plant, the acid tank has level indicators that indicate high and low levels in the control room. Both plants check the phosphate residual daily. An effective practice at one plant is to observe the addition of phosphoric acid to the primary clarifier every two hours. (It can easily be seen, as the addition point is about a foot above the water level.) This is a precaution to verify the physical flow. The operator then puts a checkmark on his logsheet if the flow appears satisfactory, and followup action is taken if there is no flow. [It should be mentioned that the original design of the nutrient addition system was such that the acid was metered separately to each of the four aeration basins. This required four metering pumps and was difficult to control. The current setup, which works effectively, is completely different. The phosphoric acid tank is now mounted on stilts at one plant above the primary clarifier (which returns sludge to the basins) so the acid can flow by gravity into the clarifier's sludge recycle pump. Gravity always works, and the operators can visually check the flow of acid.]

Aeration--An adequate and continuous supply of oxygen is necessary to keep the microorganisms healthy. Two of the plants observed had surface aerators and the third had turbine aerators. The aerators also serve the important function of keeping the wastewater and microorganisms well mixed. One plant had four aerators with 75-hp motors, two aerators per basin section. Each basin section is 92 feet long by 46 feet wide and has a capacity of 475,000 gallons. Flow through each basin is about 200 gal/min. Another plant with four basin sections (or cells) had one mechanical aerator for each cell. The aerators have 30-hp motors. Each cell is 30 feet long by 30 feet wide and has a capacity of 67,000 gallons. Flow through each cell is about 40 gal/min. The plant with two basin sections initially had problems with solids buildup on the bottom of the basins. They determined that the two mixers (in each basin) were partially counteracting each other and causing the sludge layer to form. This was corrected by hanging heavy metal plates between the two mixers in each section, which blocked the counteractive swirling and created good agitation in each of the somewhat "partitioned" sections.

At one plant the practice is to make an occasional check of the dissolved oxygen (DO) content of the basin water and to make a physical check of the aerators twice per shift to see if they appear to be operating properly. One plant that does not monitor the DO regularly has installed amp meters in a pump house, which are connected to the aerator motors. Normal readings are 25 to 30 amps. The operators observe these readings bihourly and put a check on a logsheet if the amp readings are in that range; if not, the actual reading is recorded and called to the operating supervisor's attention if the deviation is more than a couple of amps outside the normal range. The amp readings correlate well with cell wastewater DO levels of 1 to 2 ppm.

One plant recently had a problem with the stratification of DO in the top and bottom portions of the cells. The DO level at the top was about 2 ppm DO, and the bottom it was about 0.5 ppm (an unhealthy condition). The plant has installed air lances to be used during these times to promote better localized mixing. The lances have been effective in correcting the problem, and they also serve as a backup when an aerator fails or is taken out of service for a maintenance check.

Dilution water--Many coke plant biological systems are designed to include inlet dilution water to reduce the pollutant concentration of equalization tank feed to a level suitable for the microorganisms to feed on. The volume of dilution water can equal that of the wastewater. To monitor the dilution water flow, the plants have flow meters with pen recorders located in the central control room. Operators observe the readings periodically and are atuned to any alarms that signal when the dilution water pump(s) are not working. In addition, pump inspections are usually made a couple of times per shift. The operator can adjust the ratio of dilution water to wastewater. Rather than 1 to 1, his experience may tell him that 0.8 to 1 is a satisfactory ratio for the bugs. This cutback in dilution water reduces the required addition of chemicals such as phosphoric acid and antifoam, and it also increases the hydraulic retention time.

Although none of the systems observed in this study have used powdered activated carbon (PAC) addition yet, one environmental department manager was of the opinion that people planning to build biological systems should consider PAC use and its economics, because if used properly, it can replace or greatly reduce the need for dilution water. Without the need for dilution water, basin capacities, pumps sizes, etc. can be reduced considerably. Powdered activated carbon is also an effective antifoaming agent. (This is discussed later.)

Introduction of intermittent or experimental material--Caution is required in the addition of any material to a bug pond other than normally treated wastewater. The operating staff must contact the environmental department for advice and to see if the planned addition will violate conditions in the discharge permit. The environmental department may have to contact the EPA before making a decision. It is important the properties of the wastewater be known so that an evaluation can be made on whether the material will adversely affect the treatment system. Operators and supervisors at one plant said they contacted other plants (technology transfer) to see if they had experimented with the material.

If evidence shows that the material will not adversely affect the system, additions to the system should be made slowly. Operating practices at one plant included recording the amount of material added, observing the effects, making more frequent analyses and recording key operating parameters to note any changes.

Monitoring and logging of key parameters--Examples of monitoring and logging key parameters are given in Section 4.1.2. The monitoring of important operating and environmental parameters (although the latter is usually done by the environmental department, operators should understand them) is a primary operating function. Periodic monitoring is necessary for the plant to know whether the system is working properly or not.

Some monitoring does not require logging. For example, if pumps, aerators, and clarifier rakes appear to be operating fine and the control panel does not show any shutdown of this equipment, there is no need to record that information. Problems with equipment can be recorded in the operator's log book and called to the supervisor's attention. Certain key parameters should be logged, however, to show if something is out of line with the normal data. An operator usually performs this function. Examples of logsheets used by plants with well-operated systems are shown in Figures 4.1-3 through 4.1-6. These represent actual examples of the parameters and frequencies certain plants believe are important to their particular operation.

Foaming--Foaming is a phenomenon that occurs at many coke plants, and the specific reasons for its occurence are not known. One thought is that some of the organics present in coke plant wastewater may undergo saponification reactions (e.g., as in soap making) when they come in contact with lime or caustic in the ammonia stills and form surfactants, and these surfactants, after intense aeration in the basin, form foam.

One of the practices the steel industry uses to combat the foam is water spraying around the periphery of the aeration basin. One plant sprayed

FLUSHING LIQUOR ANALYSIS

MONTH
YEAR

DATE	AMMONIA STILLS															NO. 1 BY-PRODUCTS					COMMENTS
	FEED LIQUOR		ph SAMPLE BEFORE LAMELLA		RETURN FEED		STILL BOTTOMS						WASTE LIQUOR			LIGHT OIL WASTE WATER					
							NO. 1			NO. 2											
	ph	NH_3 (ppm)	ph	S.S. (ppm)	ph	S.S. (ppm)	ph	NH_3 (ppm)	S.S. (ppm)	ph	NH_3 (ppm)	S.S. (ppm)	ph	NH_3 (ppm)	S.S. (ppm)	ph	NH_3 (ppm)	Phenol (ppm)	THIOCYAN (ppm)	S.S. (ppm)	
1																					
2																					
3																					
4																					
5																					
6																					
7																					
8																					
9																					
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30																					
31																					

Figure 4.1-3. Example log sheet for flushing liquor analysis.

NO. 2 BY–PRODUCT PLANT
FLUSHING LIQUOR TREATMENT

										DATE			
AMMONIA STILLS		0800	1000	1200	1400	1600	1800	2000	2200	2400	0200	0400	0600
FEED TANK LEVEL													
FEED LIQUOR FLOW	No. 1												
	No. 2												
RETURN LIQUOR FLOW	No. 1												
	No. 2												
STEAM FLOW	No. 1												
	No. 2												
VAPOR TEMPERATURE	No. 1												
	No. 2												
STILL PRESSURE	No. 1												
	No. 2												
LIQUOR TO LAMELLA PH													
STILL WASTE PH													
LIQ. TEMP. AFTER COOLERS													
SLAKER													
WATER PRESSURE													
LIME STORAGE LEVEL													
BURNER													
C.O. GAS FLOW													
C. O. GAS PRESSURE													
STACK GAS TEMPERATURE													
AERATION TANKS													
FEED LIQUOR TEMPERATURE													
SLUDGE RECYCLE	S												
	N												
AERATION CELL TEMPERATURES	SE												
	SW												
	NE												
	NW												
CLARIFIER	RAKE AMPS												
	ACID FEED												

8 – 4	4 – 12	12 – 8
OPERATOR	OPERATOR	OPERATOR
REMARKS	REMARKS	REMARKS

Figure 4.1-4. Example log sheet for flushing liquor treatment.

WASTE LIQUOR ANALYSIS

MONTH YEAR

DATE	BIOLOGICAL OXIDATION PLANT																							
	FEED LIQUOR					AERATION TANKS										CLARIFIER OVERFLOW								COMMENTS
						SUSPENDED SOLIDS PPM				SET TEST %	SVI	VOLATILES WEIGHT %												
	pH	NH_3 (ppm)	Phenol (ppm)	Thio Cyan (ppm)	S S (ppm)	SW	SE	NW	NE			SW	SE	NW	NE	pH	NH_3 (ppm)	Phenol (ppm)	Thio Cyan (ppm)	S S (ppm)	Phosphate (ppm)	Volatiles Weight (%)	S R T (Days)	
1																								
2																								
3																								
4																								
5																								
6																								
7																								
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Figure 4.1-5. Example log sheet for waste liquor analysis.

Coke Plant Wastewater Treatment - Daily Report

Date:

Operator's name:

Sample point	Measured parameter	Time of day					
Ammonia still discharge	pH						
Equalization tank	pH						
Aeration basin inlet	pH						
Aeration basin outlet	pH						
Final clarifier outlet	pH						
Aeration basin outlet	% solids						
Recycle sludge	% solids						

Figure 4.1-6. Example log sheet for coke plant wastewater treatment.

water into the final clarifier centerwell, which was effective. Chemical antifoam agents are also in wide use. One plant added these agents at each of their aerators; another plant added them at the primary clarifier recycle sump. Still other plant people (interviewed by phone) said that powdered activated carbon works well as an antifoam agent. (The belief is that the PAC adsorbs the organics or reduces their concentration enough to hinder foaming.) It was also mentioned that PAC may reduce oxygen transfer somewhat, so anyone experimenting with PAC initially should closely monitor the dissolved oxygen content of the basin. (If the DO drops too low, the PAC addition should be decreased.)

4.1.4 Effect of Upsets/Problems

Upsets in the biological treatment system can easily result in NPDES permit excursions or violations of the permit (or agreement) with the city's municipal treatment system, depending on where the treated water is discharged. The effect on the treatment system depends on the severity of the upset. Because biological systems consist of a living biomass rather than just pollutant removal equipment, they can be severely affected by changes to their environment. Unlike mechanical treatment systems (e.g., deep-bed filtration, clarification), an upset that adversely affects or destroys the biomass can cause the biological system to be ineffective for long periods of time until a healthy bug population has been restored. The restoration will take days at least, and can take weeks and months if a massive bug kill has taken place.

Improper handling of each of the items described in the "Major Areas of O&M Concern" can cause an upset to the bio-oxidation system. Lack of attention to any of these items (e.g., performance of ammonia stills; control of basin pH, temperature, nutrient level, and dissolved oxygen concentration; proper amount of dilution water; communication; monitoring key parameters) can cause a biological system upset ranging from minor to major proportions.

4.1.5 Relationship Between O&M Practices, Upsets, and Effluent Quality

The parameters, or areas of concern, that control or affect biological treatment systems are closely related to O&M practices because the parameters depend on operator and maintenance attention to keep them within a narrow operating range. For example, basin temperature, pH, phosphate level, DO level, and pollutant levels (such as those for phenol, thiocyanate, NH_3) must be monitored frequently so that any significant change (outside their normal range) can promptly be investigated).

If effective O&M practices are not implemented in the byproducts area (e.g., ammonia stills) and the biological treatment system, any number of frequently occurring problems (e.g., lime still trays plugging) could go undetected by the operators until the result of the problem becomes apparent.

Biological systems are so sensitive that the slightest inattention could result in an upset to the system. Also, because many biological systems discharge their effluent to a POTW or outfall (rather than recycling it), upsets often result in a permit excursion.

A number relationship between O&M practices and effluent quality or excursions obviously cannot be developed. One cannot say, for example, that a plant that has three operators and monitors key parameters bihourly will have 75 percent fewer excursion than a plant that has two operators and monitors the parameters every 4 hours. A relationship between O&M and effluent quality (within permit limits or exceeding them) does exist, however, because there will be a point at which a reduction in operators and decrease in monitoring frequency will result in an excursion. Section 7 describes problems that cause noncompliance incidents, and many are related to O&M practices.

Some specific examples of excursions (at coke plant wastewater treatment systems) and causes thought to be related to O&M practices are summarized in Table 4.1-1. This information is extracted from noncompliance reports submitted from iron and steel plants to their state agencies.

REFERENCES FOR SECTION 4.1

1. United States Environmental Protection Agency. Development Document for Effluent Limitations Guidelines and Standards for the Iron and Steel Manufacturing Point Source Category. Volume II Effluent Guidelines Division, WH-552, Washington, D.C. 20460. EPA 440/1-82/024, May 1982.

2. Wear, M. R., J. A. Grantz, and R. J. Thompson. Biological Treatment of Coke Plant Waste Using an Integrated Clarification Concept. Presented at Symposium on Iron and Steel Pollution Abatement Technology for 1980. Philadelphia, Pennsylania. November 18-20, 1980.

TABLE 4.1-1. EXAMPLES OF COKE PLANT WASTEWATER TREATMENT PERMIT EXCURSIONS

Cause of problem	Parameter/pollutant exceeded	Date	Actual concentration, mg/liter	Allowable concentration, mg/liter
Failure of caustic pumps on crude ammonia still	Phenol, kg/day	10/20/77	7.9	2.2
		10/27/77	18	
Upset of biological treatment plant caused by insufficient steam stripping	Total cyanide, kg/day	4/1/81	55.7	53.9
		4/7/81	84.7	
		4/8/81	70.8	
Excessive lime addition at slaker	pH, units	4/21/81	10.5	8.5
Caustic control valve malfunction at ammonia still. The still waste containing the caustic was pumped to the biological treatment plant causing the upset.	Phenol, kg/day	12/8/81	42.4	2.2
		12/9/81	31.8	2.2
		12/12/81	10.2	2.2
		12/13/81	4.3	2.2
		12/14/81	3.5	2.2
		12/15/81	> 2.2	2.2
	pH, units	12/14/81	8.8	8.5
Ammonia liquor tank overflow	Ammonia, mg/liter	1/20/82	6.2	4.5
Ammonia sulfate recovery area. Tank overflow.	Ammonia, lb/day (net)	2/27/79	3333	
Weak ammonia liquor storage tank overflow	Phenol, mg/liter	2/1/82	40	
	Ammonia, mg/liter	2/1/82	79	

4.2 BLAST FURNACE

Blast furnace treatment systems, which do not vary much from plant to plant, are equipped with recycle systems with a thickener/clarifier for solids removal, a cooling tower, and a chemical treatment system for scale control. Several plants use alkaline chlorination to remove ammonia and cyanide from blowdown water. Discharge flow rates under 100 gal/ton are achieved at a number of plants. In this study, three blast furnace systems were visited; two of them use alkaline chlorination.

4.2.1 Arrangement of Treatment Components

A model blast furnace recycle system is shown in Figure 4.2-1 to illustrate a mass balance for such a system.[1] Although systems vary greatly, this diagram shows the basic flows and relationships in a blast furnace recycle system. Figures 4.2-2 and 4.2-3 show the layout of the systems at two of the plants visited. Plant A is more typical of blast furnace recycle systems in that it has a cooling tower, but the sludge is not dewatered before disposal. This plant uses alkaline chlorination to treat blast furnace blowdown water, which is approximately 5 percent of the recycle stream. Although alkaline chlorination is not a widespread practice for treating steel industry wastewaters, it is one of the BAT alternatives for blast furnace blowdown control.

Plant B does not have a cooling tower; makeup and blowdown are used to control temperature. Blowdown therefore can be quite high (up to 40%). Three disc-type vacuum filters are used to dewater the sludge.

At a third plant visited, blast furnace scrubber wastewater is discharged first to a primary sedimentation pond (which also receives sinter plant wastewater), then to a holding pond with oil skimmers, and finally into a stabilization lagoon. Water from this lagoon combines with that from another large lagoon (which treats all other plant process wastewater except that from the coke plant). The combined flow goes to a pumping station, where approximately 65 percent is recycled to a reservoir for plant reuse and 35 percent is further treated by alkaline chlorination and gravity sand filtration before discharge to an outfall.

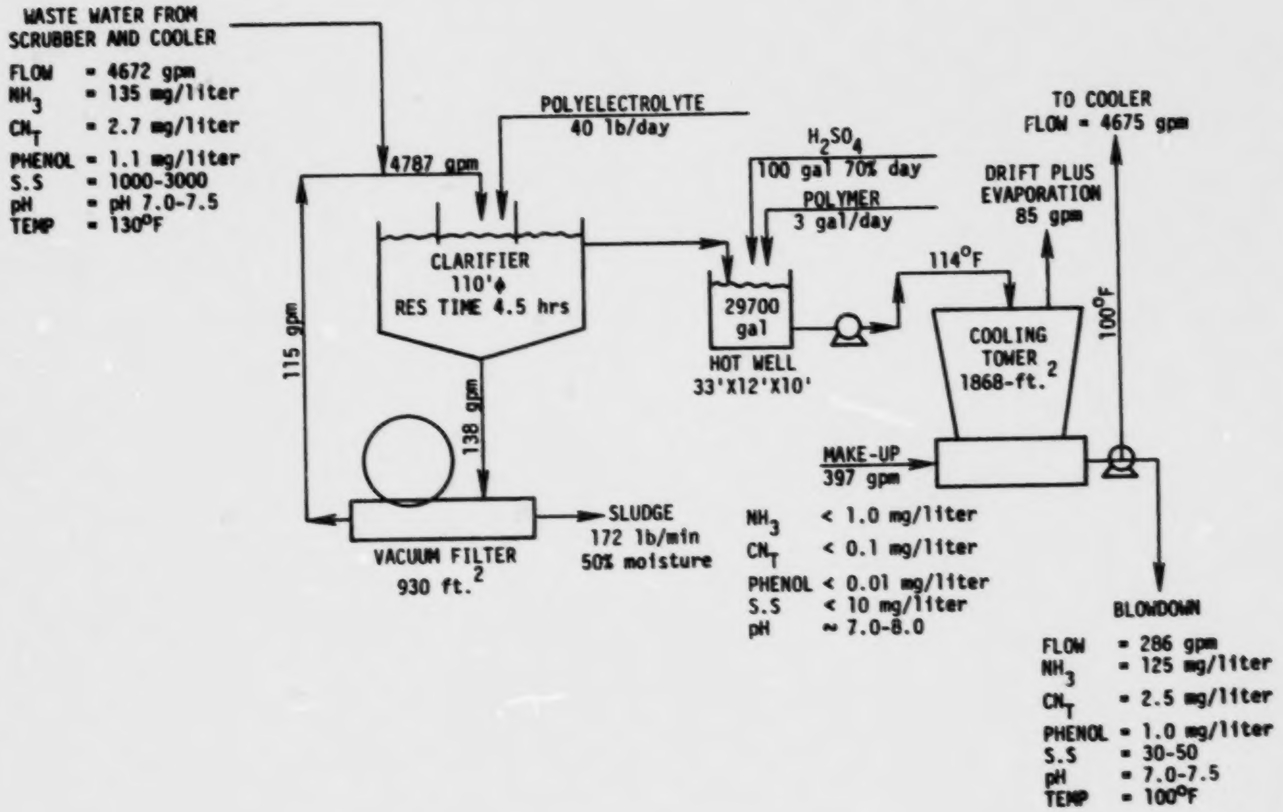

WASTE WATER FROM
SCRUBBER AND COOLER
FLOW = 4672 gpm
NH$_3$ = 135 mg/liter
CN$_T$ = 2.7 mg/liter
PHENOL = 1.1 mg/liter
S.S = 1000-3000
pH = pH 7.0-7.5
TEMP = 130°F
4787 gpm
POLYELECTROLYTE
40 lb/day
CLARIFIER
110'ϕ
RES TIME 4.5 hrs
115 gpm
138 gpm
VACUUM FILTER
930 ft.^{2}
SLUDGE
172 lb/min
50% moisture
H$_2$SO$_4$
100 gal 70% day
POLYMER
3 gal/day
29700
gal
HOT WELL
33'X12'X10'
114°F
DRIFT PLUS
EVAPORATION
85 gpm
TO COOLER
FLOW = 4675 gpm
100°F
COOLING
TOWER
1868-ft.^{2}
MAKE-UP
397 gpm
NH$_3$ < 1.0 mg/liter
CN$_T$ < 0.1 mg/liter
PHENOL < 0.01 mg/liter
S.S < 10 mg/liter
pH ~ 7.0-8.0
BLOWDOWN
FLOW = 286 gpm
NH$_3$ = 125 mg/liter
CN$_T$ = 2.5 mg/liter
PHENOL = 1.0 mg/liter
S.S = 30-50
pH = 7.0-7.5
TEMP = 100°F

Figure 4.2-1. Material balance on treatment unit for blast furnace gas scrubber and cooler water for model plant[1] (adjusted to add cooling tower loss).

Courtesy of Wong Chong, G. M., and S. G. Caruso. An Evaluation of the Treatment and Control Technology Recommended for the Blast Furnace (Iron) Wastewater. Mellon Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania. August 1976.

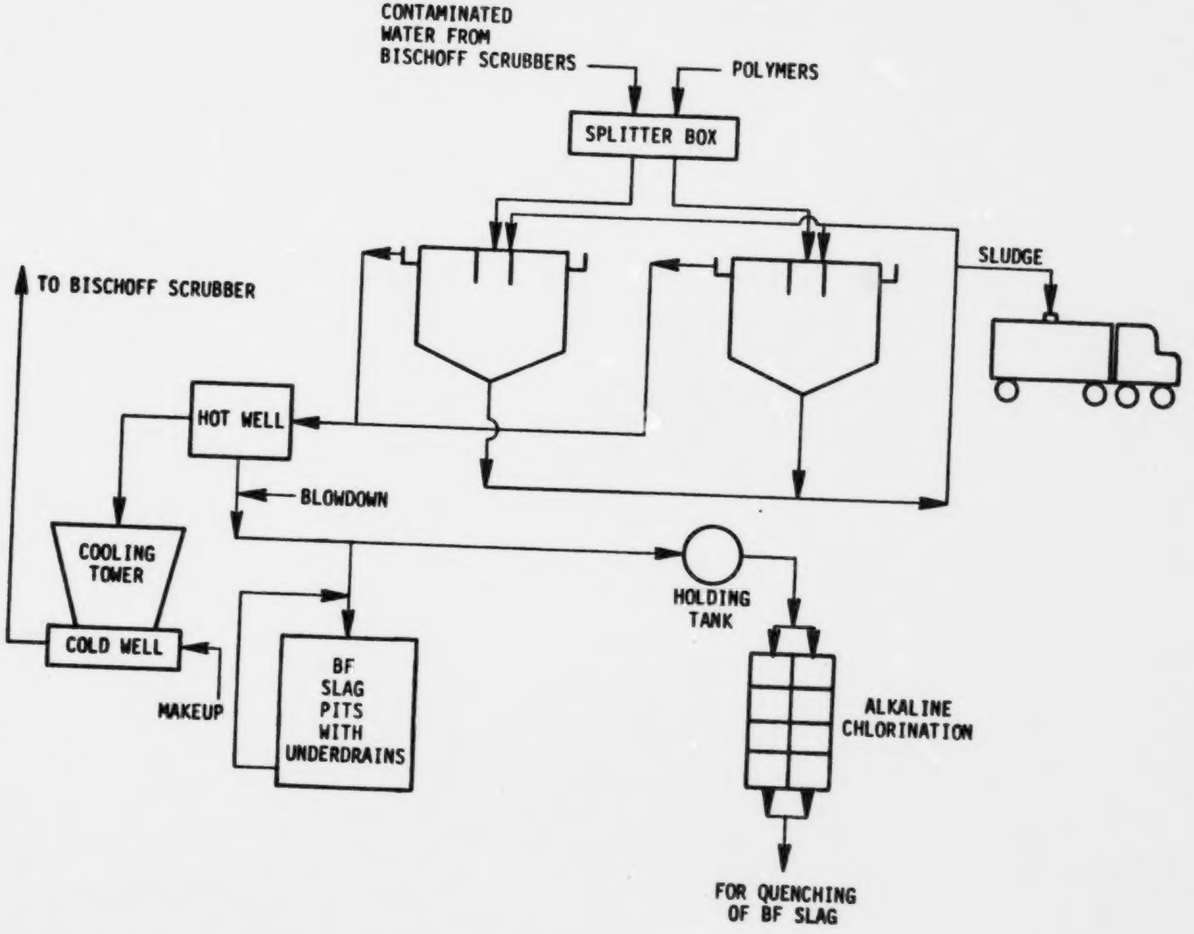

CONTAMINATED
WATER FROM
BISCHOFF SCRUBBERS
POLYMERS
SPLITTER BOX
SLUDGE
TO BISCHOFF SCRUBBER
HOT WELL
BLOWDOWN
COOLING
TOWER
COLD WELL
MAKEUP
BF
SLAG
PITS
WITH
UNDERDRAINS
HOLDING
TANK
ALKALINE
CHLORINATION
FOR QUENCHING
OF BF SLAG

Figure 4.2-2. Flow diagram of blast furnace recirculation and blowdown treatment system at a visited plant.

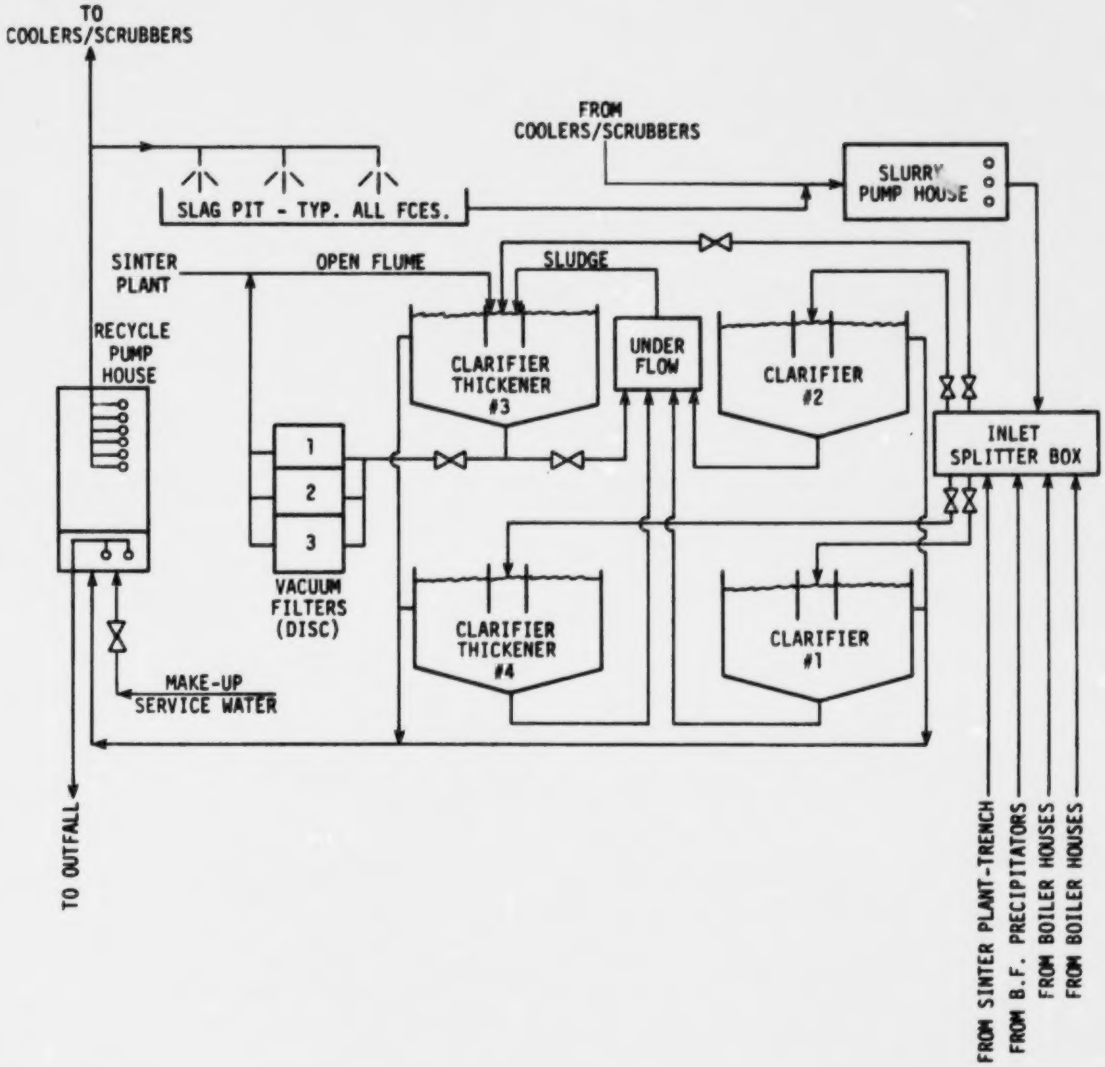

TO COOLERS/SCRUBBERS
FROM COOLERS/SCRUBBERS
SLURRY PUMP HOUSE
SLAG PIT - TYP. ALL FCES.
SINTER PLANT
OPEN FLUME
SLUDGE
RECYCLE PUMP HOUSE
CLARIFIER THICKENER #3
UNDER FLOW
CLARIFIER #2
INLET SPLITTER BOX
1
2
3
VACUUM FILTERS (DISC)
CLARIFIER THICKENER #4
CLARIFIER #1
MAKE-UP SERVICE WATER
TO OUTFALL
FROM SINTER PLANT-TRENCH
FROM B.F. PRECIPITATORS
FROM BOILER HOUSES
FROM BOILER HOUSES

Figure 4.2-3. Flow diagram of blast furnace gas cleaning wastewater treatment system at a visited plant.

Splitter Box--

The splitter box is nothing more than a steel box that serves three functions: 1) to split the flow between multiple clarifiers, 2) to screen out large debris, and 3) to serve as a mixing point for polymer addition. It also provides a convenient spot for checking inlet flow to the system, distribution to the clarifier/thickeners, and polymer flow.

Thickeners--

Multiple thickeners/clarifiers are common in blast furnace wastewater systems. They provide the needed hydraulic surge capacity, and they permit continued operation while one unit is down for cleaning or repair. In System A (Figure 4.2-2), the sludge is recirculated to maintain a solids content of 15 to 20 percent. In System B, underflow is taken from the clarifier and fed to a thickener. The sludge is recirculated and then discharged, as required, from the recycle line to the disc filters.

Clarifier/thickener design is usually based on an overflow rate of 0.5 to 1.5 gpm/ft^2.[2] The specific values at the two plants visited were 0.63 and 0.5.

Cooling Tower--

In blast furnace systems, a cooling tower is normally used to achieve temperature control without the need for excessive blowdown. In addition to maintaining low temperature in the scrubber inlet water (with lower gas moisture loading), a lower water temperature helps to minimize the buildup of alkali deposits within the recycle system. The water temperature is interrelated with water/chemical stability.

In the absence of a cooling tower, maintaining water temperature in the range of 90° to 120°F requires much higher blowdown rates. As a result, pollutant concentrations are lower than those in a tight recycle system.

Alkaline Chlorination--

In some systems, alkaline chlorination is used to treat the blowdown for ammonia and cyanide removal. After clarification, the blowdown flows into a flume and then to final pH adjustment tanks, where lime is used to adjust the pH to an acceptable chlorination level. After final pH adjustment, the wastewater flows by gravity to a chlorine reaction chamber consisting of a series of connected concrete tanks with or without a top.

Effluent from the chlorine reaction chamber may be used for slag quenching or discharged. Dechlorination may be practiced with the use of sulfur dioxide or other reagents.

4.2.2 Identification of Major Areas of O&M Concern

The major areas of concern in blast furnace recycle systems are:

- Control of pH
- Phenol removal
- Cyanide removal
- Ammonia removal
- Dissolved solids, scaling control
- Sludge handling
- Hydraulic balance, maintenance of tight recycle
- Temperature of recycle water
- Chemical additions

Control of pH--

Control of pH is necessary because both lime particles and ammonia in the wastewater tend to make the water alkaline. Dissolution of the carbon dioxide in the blast furnace gas into the water helps to lower pH, but this also can cause formation of calcium carbonate. The higher the pH, the greater the tendency for calcium precipitation and scaling. None of the systems visited used acid, but one plant had installed an acid metering system.

Pollutant Removal--

A pH of 7 or less is required to control cyanide and phenol in the wastewater and to reduce scaling. Unfortunately, this pH level is not good for ammonia removal. Specific techniques for ammonia reduction are alkaline chlorination and air stripping. In a system with a cooling tower, some ammonia will be air-stripped across the tower. At one plant, caustic is added to the blowdown to raise the pH to 11. The stream is then introduced into a stripping column, where warm air is blown through the water.[3] A more common approach is alkaline chlorination (discussed earlier in Section 3.8), which also converts some cyanide.

Figure 4.2-4 illustrates the influence of pH on phenol and cyanide removal. Figure 4.2-5 shows a relationship between cyanide and alkalinity. Control of pH below 7 is desirable to limit carryover of these pollutants. Figure 4.2-6 shows the relationship between pH and ammonia concentration; the higher the pH, the lower the ammonia solubility. Because high pH promotes scaling, however, it is desirable to maintain pH in the 7 to 8 range, or lower.

In alkaline chlorination, the major areas of concern are:

- Safety in handling chlorine, caustic, and SO_2 (if used)
- Control of chlorine addition
- Control of lime or caustic addition for pH elevation
- Monitoring of chlorine residual
- Control of dechlorination system, if used

The safety of these systems is particularly critical because chlorine is a toxic gas and can be released both from the chlorine addition system and from the reaction tanks. Control of reagent additions requires close monitoring because of the sensitivity of the reactions (as described in Section 3.8). Some means of influent flow rate control is necessary to maintain a constant ammonia input rate.

Dissolved Solids, Scaling Control--

The principal failures in blast furnace gas cleaning systems are due to the plugging of spray nozzles, deposits in venturi or orifice throats, and the closing of transport pipes by precipitated materials. Chemical analyses of such materials show them to be mainly calcium carbonate.[4,5] Suspended materials do not seem to be a controlling factor, as a properly designed treatment system affords good removal. Carbon dioxide and calcium oxide in the gas react with the wash water to change the calcium carbonate equilibrium. Other materials in the gas (e.g., iron, sodium, potassium, magnesium, sulfate, and ammonia) add incrementally to the total dissolved solids. The different levels of these materials depend on the furnace burden and method of operation.

Formation of carbonate scale is a common problem in blast furnace gas scrubber water systems. Calcium carbonate is usually the chief ingredient of scale formation because of its low solubility in water, which decreases

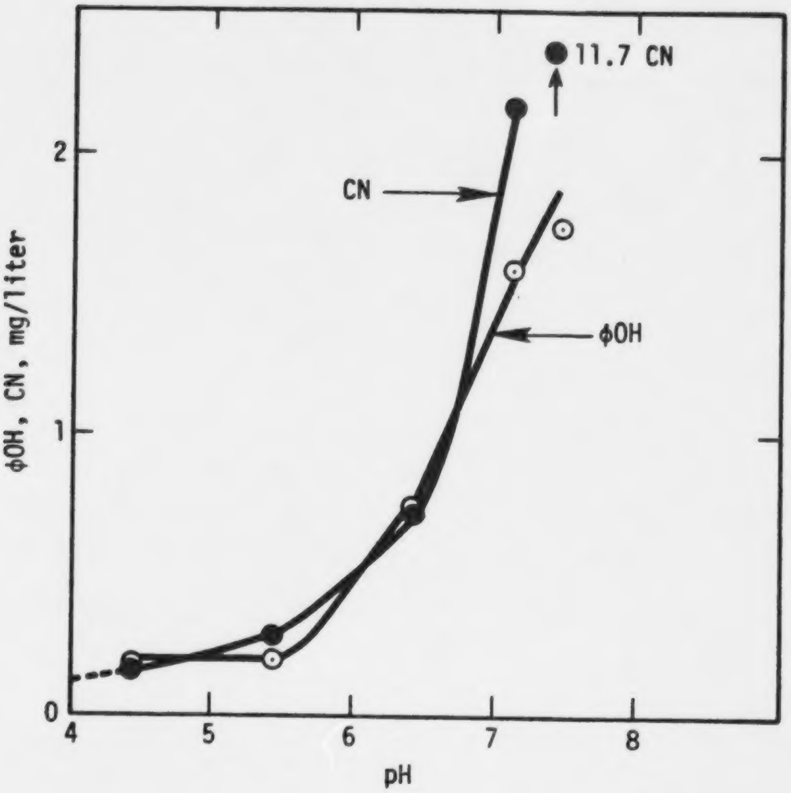


Figure 4.2-4. Relationship between scrubber water pH and cyanide and phenol concentrations.

Courtesy of Wong Chong, G. M., and S. G. Caruso. An Evaluation of the Treatment and Control Technology Recommended for the Blast Furnace (Iron) Wastewater. Mellon Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania. August 1976.

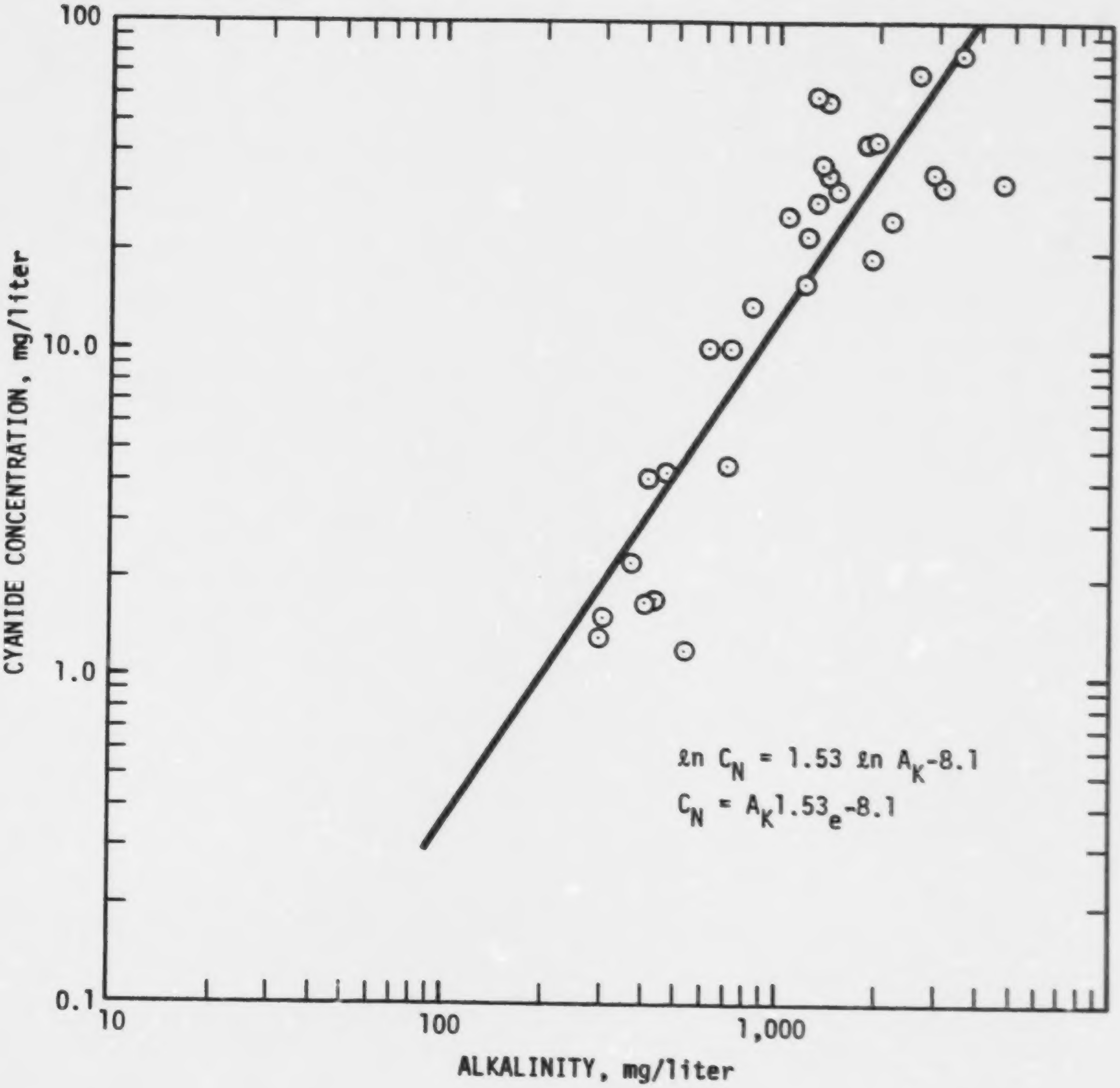


Figure 4.2-5. Relationship between cyanide concentration in the scrubber wastewater and alkalinity.

Courtesy of Wong Chong, G. M., and S. G. Caruso. An Evaluation of the Treatment and Control Technology Recommended for the Blast Furnace (Iron) Wastewater. Mellon Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania. August 1976.

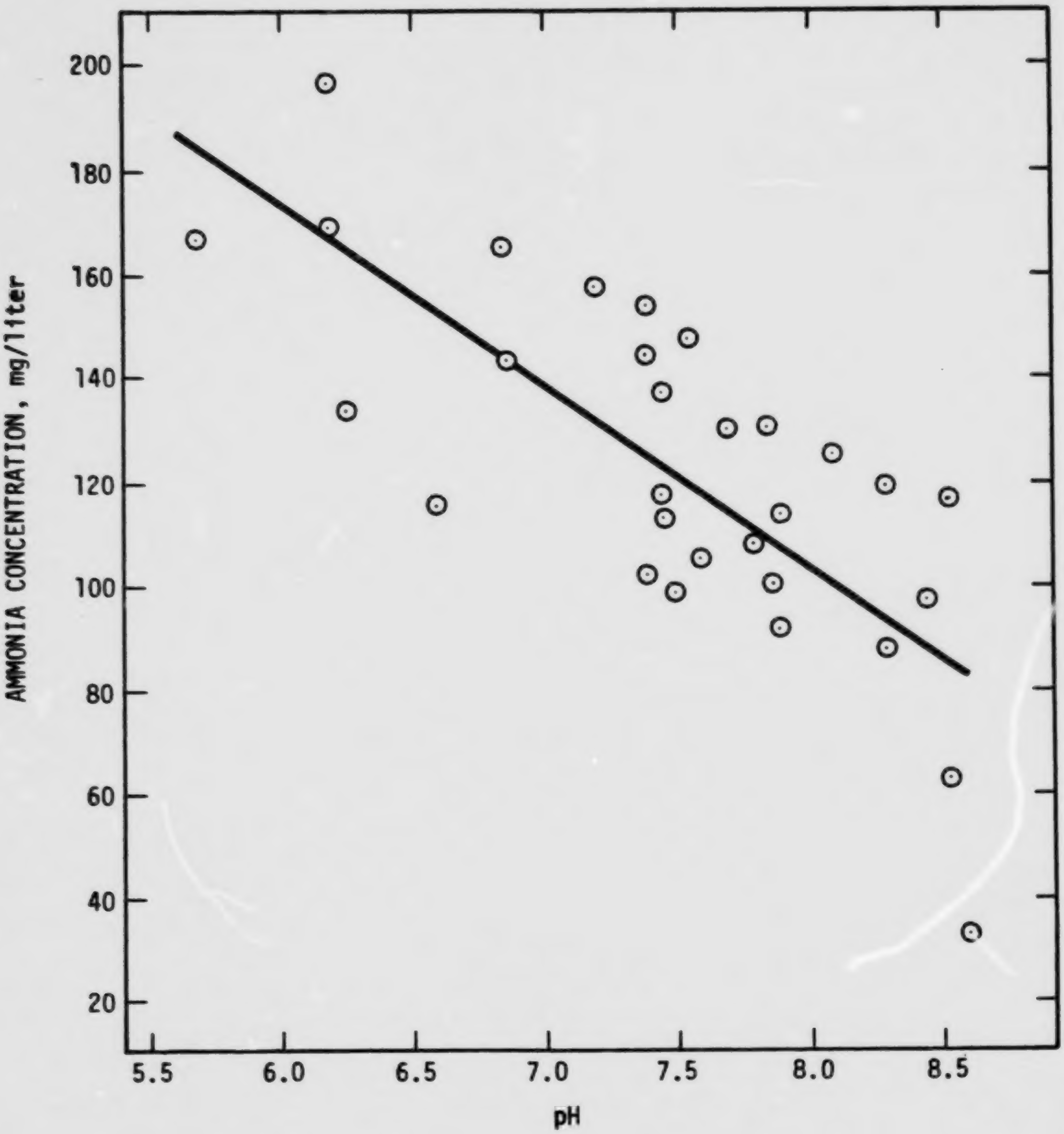


Figure 4.2-6. Effect of pH on the ammonia concentration in recycle blast furnace gas scrubber water.

Courtesy of Wong Chong, G. M., and S. G. Caruso. An Evaluation of the Treatment and Control Technology Recommended for the Blast Furnace (Iron) Wastewater. Mellon Institute, Carnegie Mellon University, Pittsburgh, Pennsylvania. August 1976.

as the temperature increases. The factors that affect scale formation are temperature, calcium, magnesium, silica, alkalinity, dissolved solids, and the pH of the water.

Two indexes that are used to predict the scaling tendency in blast furnace recycle systems are Langlier's Saturation Index and the Ryznar Stability Index, which were defined earlier in Section 3.2.

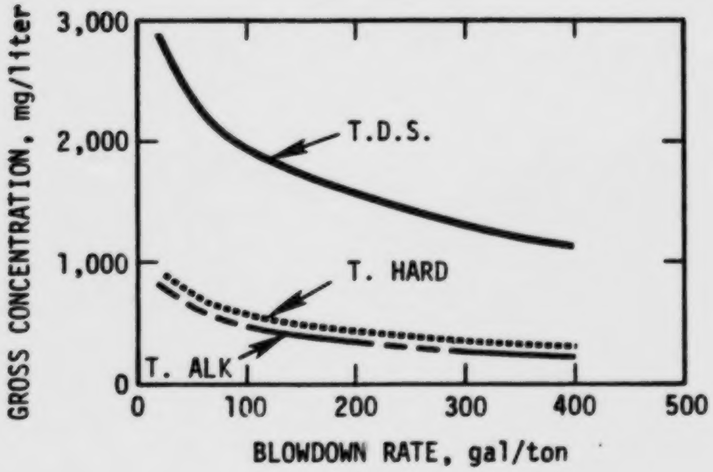
Sludge Handling--

Proper movement and removal of sludge from the wastewater circuit are very important. Because of the abrasiveness and quantities of sludge removed from blast furnace treatment systems, however, its handling is considered a major area of O&M concern. In a thickener/clarifier, rakes continuously move the sludge to the collection sump. If the solids concentration becomes too great (e.g., 35 percent reported at one plant) before the sludge is removed from the thickener, it is too thick to move and can damage the rake and rake-drive mechanism. This will cause a thickener/clarifier outage until the situation is corrected.

Many plants recycle the sludge back to the thickener/clarifier to add a seed material to promote settling and to keep the solids in motion to prevent settling in pipes. This is good practice, but it causes wear to sludge pumps and piping.

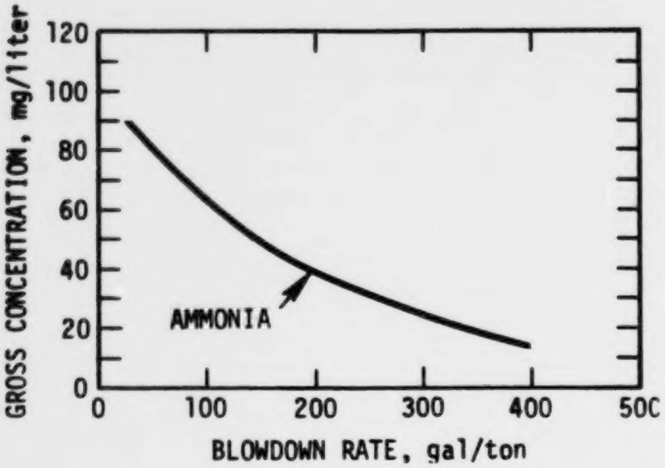
Hydraulic Balance--

A commonly cited problem concerns maintaining hydraulic balance, or more specifically, minimizing intermittent extraneous water inputs to the system, which increase blowdown.[5,6] Proper hydraulic balance is especially critical for tight recycle systems (e.g., <100 gal/ton). Republic Steel (Cleveland) has reported on their substantial efforts to eliminate miscellaneous sources of water input to their blast furnace recycle system to decrease blowdown.[5] None of the plants visited reported excessive scaling problems. In one system, considerable water (75 to 80%) was discharged in the sludge and in the regular blowdown. In another system, which had no cooling tower, blowdown was high to control temperature. As recycle systems are closed more tightly, both dissolved solids and pollutant concentrations increase (as illustrated in Figures 4.2-7 and 4.2-8).[5]

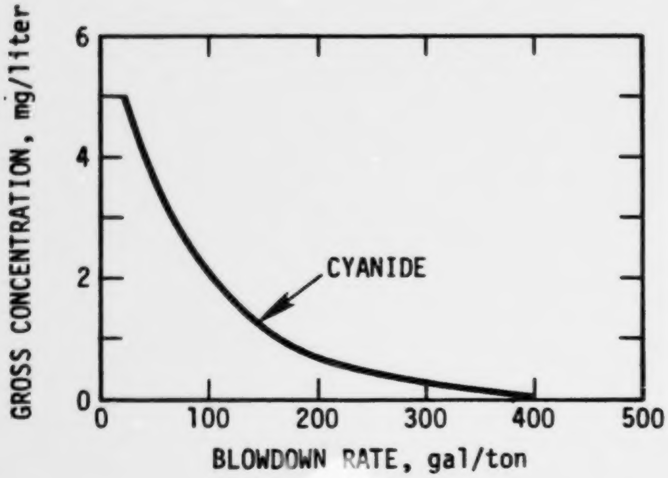


Total dissolved solids, total hardness, and total alkalinity concentration as a function of blowdown rate (November 1979 - July 1981).

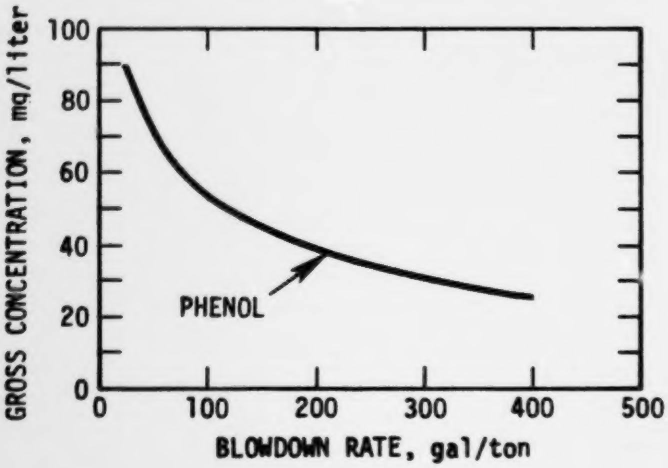
Figure 4.2-7. Example of scaling indicators vs. blowdown rate.[5]



Ammonia gross concentration as a function of blowdown rate (November 1979 - July 1981).



Total cyanide gross concentration as a function of blowdown rate (November 1979 - July 1981).



Phenol gross concentration as a function of blowdown rate (November 1979 - July 1981).

Figure 4.2-8. Examples of pollutant concentrations vs. blowdown rate.[5]

Recycle Water Temperature--

The blast furnace top gas temperature is a function of many factors, and it may vary from more than 1000°F (with abnormal furnace filling) to less than 212°F. The normal range, however, is 250° to 400°F.

Blast furnace gas leaving a wet scrubber is saturated with moisture. The temperature of the gas determines the moisture content of the gas, and small differences in temperature cause the moisture to vary drastically. For example, gas at 100°F will carry 20 grains per cubic foot, whereas gas at 120°F will carry more than 34 grains per cubic foot.

Excessive moisture decreases the effective calorific value of the gas and also causes heavy condensation in gas mains and burners. It is therefore desirable to cool the gas in the scrubbers or in the gas coolers following these scrubbers by maintaining a low temperature in the water going to the scrubbers.

Chemical Additions--

Virtually every system utilizes deposit control agents to prevent fouling in high recycle systems and polymers to enhance removal of suspended solids. The specific chemicals used, points of additions, usage rates, and program monitoring are usually left to the discretion of the chemical supplier. Calcium levels normally run from 100 to 600 ppm with methyl orange alkalinity of 300 to 600 ppm.[4] These systems generally operate with a positive Langlier index.[2,4] Actual cycles of concentration (number of passes a portion of the wastewater makes in the recirculation loop before being blown down) are best measured by the chloride ratio of the recirculating water to the makeup water. Deposition can occur in the scrubber, scrubber nozzles, cooling tower, and lines to and from the scrubber. Deposit control agents are effective when used in a controlled and monitored program.[4,5] At one plant, the chemical addition was made at the hot well of the cooling tower.

Solids removal in blast furnace systems is greatly enhanced by polymer addition. Typically, both a cationic and anionic polymer are used; the point of addition is at the inlet to the clarifier/thickener. The cationic polymer neutralizes the particle charge, whereas the anionic polymer serves as the flocculating agent. Although the chemical supplier oversees the chemical addition program, the system operators must periodically check the flow of chemicals to ensure that the feed tank does not run dry and the lines do not plug.

4.2.3 Identification of Effective O&M Practices

The O&M concerns at the operating level focus primarily on the condition of the equipment and the parameters used for daily monitoring of the system. Effluent water quality, on the other hand, is the concern of the environmental department.

The forms the operators use indicate the type of monitoring they consider important. (See sample forms in Figures 4.2-9 through 4.2-12). In addition to information on these forms, most plants are also concerned with the items shown in Table 4.2-1. Specific areas of concern are discussed in the following sections.

TABLE 4.2-1. CRITICAL ITEMS IN BLAST FURNACE RECYCLE SYSTEM

Equipment item	Critical parameters
Sludge pumps	Pluggage, erosion
Sludge lines	Pluggage, erosion
Clarifier rake	Torque
Polymer feed	Mixing, flow
Water pumps	Temperature, erosion, flow

pH Control--

Although many systems have been designed for the addition of sulfuric acid to control pH, this approach was not necessary at the plants visited. Generally, acid feed is not required if blowdown rates are above 5 percent.[2] Two of the plants used alkaline chlorination when close control of pH is required.

At one plant, oxidation reduction potential (ORP) and pH are critical indicators of the completeness of reactions during the alkaline chlorination process. Unfortunately, maintenance requirements for the pH and ORP probes are high because of scaling problems. The probes are inspected daily and cleaned as necessary, and spare probes are maintained. Also, the plant experiments with new types of probes as they become available. Five pH

Makeup water rate:
Blowdown rate:

Conductivity:
Alkalinity:
Temperature:

No. of sludge loads:
Average percent solids in sludge:

	Clarifier/thickener No.			
Parameter	1	2	3	4
Flow rate				
Water elevation				
Torque				

Figure 4.2-9. Example of a blast furnace wastewater treatment system daily report.

Name:
Date:
Turn:

		Time			
C/T No. 1	pH				
	Turbidity				
	Temperature				
	Total dissolved solids				
C/T No. 2	pH				
	Turbidity				
	Temperature				
	Total dissolved solids				
C/T No. 3	pH				
	Turbidity				
	Temperature				
	Total dissolved solids				
C/T No. 4	pH				
	Turbidity				
	Temperature				
	Total dissolved solids				
Splitter box	pH				
	Sludge settle time				
	Polymer settle time				
Recycle pumphouse	pH				
	Turbidity				
	Temperature				
	Total dissolved solids				
		Polymer tank level			

Recirculating pump ammeter	1	2	3	4		Blowdown pump ammeter	1	2	3	4

Recycle pH:
Acid pump operating: Yes ____ No ____
Dispersant feeding: Yes ____ No ____
Recirculating pump ammeter: Pump No. 1 ____ 2 ____ 3 ____ 4 ____
Blowdown pump ammeter: Pump No. 1 ____ 2 ____ 3 ____ 4 ____

Figure 4.2-10. Clarifier/thickener (C/T) operator report.

Date:

Parameter	Time[a]					
Operator's name						
Influent NH_3, mg/liter						
Influent flow, gal/min						
Cl_2 feed rate, lb/day						
Reaction tank ORP:						
Instrument						
Lab test						
Reaction tank pH:						
Instrument						
Lab test						
Ejector flow, gal/min						
Effluent NH_3, mg/liter						
Residual Cl_2:						
Free, mg/liter						
Fixed, mg/liter						

[a] Example: every 4 hours.

Figure 4.2-11. Example of alkaline chlorination system report.

Date:

Operator's name:

Recirculation rate:

Makeup water rate:

Blowdown rate:

	Parameter measurement				Chemical additive pumping rates[b]		
Time[a]	pH	Alkalinity	Conductivity	Hardness	Polymer	Deposit agent	Other

Comments:

[a] Example: every 4 hours.

[b] Example: every 8 hours.

Figure 4.2-12. Example of a blast furnace gas cleaning system - daily water report

probes and two ORP probes are used in one system. The pH probes are used in the mixing tank and final pH adjustment tanks. In the adjustment tank, two probes are used to check each other. If the difference between pH readings is too great, an alarm sounds in the control room. The ORP probes are located in the final effluent tank of the chlorine reaction tank.

The most effective O&M practice is frequent manual checking of pH readings. One plant checks the pH of the blowdown twice a shift and the pH at several other locations in the system once a shift. Another checks pH at several locations once a shift. It has been suggested that standard solutions of 6 and 9 pH be used to calibrate pH probes rather than the usual standards, which are outside of this control range.

Pollutant Removal--

The wastewater treatment plant operators normally do not monitor phenol, cyanide, and ammonia levels except when alkaline chlorination is used. Other than maintaining pH control, the operators have little control of these pollutants because they are largely a function of system design, type of water used to quench the coke and the blast furnace operation (i.e., raw materials and temperature).

Control of these pollutants was not cited as a problem at any of the three plants visited.

Alkaline chlorination of blowdown is designed to remove ammonia and cyanide. Control of pH is the major control variable in these systems. In addition, the operator should periodically measure the inlet ammonia to adjust the chlorine feed rate. Outlet ammonia should be measured periodically to check removal efficiency. Chlorine residual should be monitored to maintain the residual below 1 or 2 ppm. At one plant, the operator runs all of the above analyses in a field lab twice a shift. The operator uses a graph in the control room to show the final pH adjustment tank set point vs. ammonia concentration. Another graph in the control room shows chlorine feed rate (lb/day) vs. ammonia concentration (mg/liter) for flows between 100 and 400 gal/min. Ammonia was originally measured by a continuous NH_3 monitor; however, because the monitor was not reliable, samples are taken from the wastewater surge tank twice a shift and analyzed for NH_3. Adjustments to the lime and chlorine feed are based on the incoming NH_3 concentration. The operator samples, measures, and records the ammonia.

Dissolved Solids, Scaling Control--

Scaling is a concern in tight recycle systems. The major control variable the operator has at his disposal is maintenance of chemical feed. Some experimentation with softening has been reported.[5] Scaling was not reported as a major problem at the plants visited, but none of these plants had tight recycle systems. At one plant, the operator monitored the hardness, alkalinity, and conductivity on each shift. These parameters were also closely monitored by the chemical supplier's field engineer. This plant added a deposit control agent to the hot well of the cooling tower. Plant B adds an antifoulant and dispersant at the main recirculation sump.

Long-term analyses of hardness, alkalinity, and conductivity and the use of graphical plots versus time are necessary to detect and correct for scaling trends. In all of the plants studied, this is the responsibility of the water treatment engineers and the chemical suppliers rather than the operators. Although the Langlier or Ryznar indexes did not appear to be used at any of the plants visited, they have been reported to be useful parameters for monitoring scaling tendencies.[2,4,6]

The criteria for blowdown at plant A are as follows:

- High level in cooling tower wells
- Turbidity over 4000
- Conductivity over 500
- pH over 8.2
- Hardness over 1000

Sludge Handling--

Sludge handling starts with control of sludge level and density in the thickener and continues through the sludge dewatering and disposal operations.

The primary problem with thickeners/clarifiers results from objects such as hard hats, iron bars, tools, and numerous other items being thrown into them and plugging the sludge lines. This problem can be solved by installing a heavy wire screen across the top of the clarifiers.

At one plant, the operator relies on two different means to alert him that the rake was not operating: 1) a high torque alarm, and 2) personally observing the liquid going to the filter. The alarm indicates that the rake is jammed. A low level of solids in the clarifier underflow is also indicative of an inactive rake. The clarifier rakes are equipped with an automatic lifting device that raises the rake if it should bind. The underflow from up to three of the four clarifiers goes to the fourth clarifier, which is operated as a thickener. The primary purpose of the thickener is to store and condition the sludge. Thickener overflow goes to the recycle sump. At this particular plant, sludge is pumped from the thickener to three disc filters, which replaced drum filters that had inadequate capacities. Disc filters were chosen because they provide a large filtration area within limited floor space. Each filter consists of eight 8-ft-diameter discs along a horizontal shaft, each of which has 10 pie-shaped steel perforated sections covered with filter cloth. If a filter cloth is torn, it is relatively easy to remove the bad section and replace it with a new section. When the cloth has been replaced two or three times, the sections (called sectors) are replaced because they tend to erode, and the resulting rough surface tears the cloth. This problem compounds; if a tear occurs in the filter cloth, the slurry that is rapidly sucked through the tear erodes the sector, and the eroded sector will soon tear the next filter cloth.

When a sector rotates into the cake discharge position, it is pressurized and the cloth balloons out slightly to break the cake. Doctor blades are provided at this point to help knock the cake off. If clearances are not well adjusted, the doctor blade will scrape against the cloth and abrade it. Operators must maintain a fairly close watch on the filter to ensure that it is operating properly.

Good level control in the filter basin is important. If the slurry depth is too low, there is not sufficient time to build a good cake. Not only does this reduce the rate of solids removal, but the thinner cakes are more difficult to break off the cloth. If the level in the filter pan gets too low, it can actually break the vacuum in the filter by allowing the sectors to suck air. A responsive level control is necessary for good filter operation.

Initially, the sludge line at one plant ran from the bottom of the thickener directly to the filter through a level control valve mounted near the filter, and the line plugged repeatedly. The problem was solved by installing a recirculation line that teed off right behind the level control valve and went back to the thickener. The level control valve was mounted as close as possible to the filter basin. This recirculation solved the plugging problem. The sludge continuously recirculates whether or not the filter operates.

The plant has used progressive cavity pumps, diaphragm pumps, and centrifugal pumps to pump the sludge. The progressive cavity pumps were fairly high-maintenance items, and the check valves on the diaphragm pumps failed and had to be replaced repeatedly. The plant is currently using a centrifugal pump and is reasonably satisfied with its performance. The pump is geared down to run slow to minimize sludge abrasion.

The plant also had a problem with water going over the top of the water/air separator into their vacuum pump. This would occur when the filtrate pump or the level control device in the separator failed. The problem was solved by putting a barometric seal on the separator. The vapor pipe from the top of the separator was run up 34 ft and then back down to the vacuum pump. Nash vacuum pumps are now used on all the filters, replacing the previously used reciprocating-type vacuum pumps.

Six-inch sludge lines are connected to the three vacuum filters in this plant. Long-radius elbows were used throughout the system. Cleanout taps were also provided at various points along the sludge line.

Preventive maintenance is performed on a scheduled basis. The clarifier gear box oil is changed every 6 months. Every week the maintenance crew goes through the plant to check and lubricate all the pumps and other moving equipment. This is known as the "oil run." Operators are trained to do minor maintenance jobs. If a pump is not working, the operator checks such common things as whether the suction line is plugged. If it is, the operator cleans the line and replaces it. If the problem is more major, such as a badly worn pump impeller, the operator contacts the maintenance department for the repair. Operators receive safety training for this work. If an operator is not capable of running the plant and doing these minor maintenance jobs, he/she can be transferred out of the department. During the day turn, there are two operators (one settler operator and one helper) and an operating supervisor. The supervisor is not on duty during the night turn, but he can be called if a major problem arises.

This plant has developed an interesting way to check for plugged sludge lines. The sludge pump is turned off, and the valves are left open. If the sludge line is open, gravity will cause the sludge to flow back into the clarifier and the pump will rotate backwards. This backwards rotation verifies open lines. This is applicable only if centrifugal pumps are used.

At Plant A, sludge is not dewatered; instead, it is shipped out in trucks when the solids level reaches 15 to 20 percent. Sludge from the thickeners is kept moving by recycling it back to the thickeners when it is not being pumped into trucks. Nagle sludge pumps are used, and they work well.

The sludge pipe lines at Plant A were originally plastic-lined for their protection, but the abrasiveness of the sludge, combined with a high pump rate, caused the lining to separate. This caused considerable plugging and fouling of the pump. The lining has been removed from the pipes and the pump rate has been slowed down. This mode of operation has allowed satisfactory movement of sludge with minimal problems. The plant is currently evaluating stainless steel for elbows where wear is greatest.

Hydraulic Balance--

Hydraulic balance is of concern as operators tighten the recycle system to minimize blowdowns. A discussion of the effective practices used by Republic is given in Reference 5.

At one plant visited, the recirculation system has two clarifiers and two clarifier/thickeners. All four are 20 feet in diameter. The clarifiers have 15-foot side walls, and the clarifier/thickeners have 20-foot side walls. Temperature of the water recycled to the scrubbers is controlled by makeup (service) and blowdown of the excess water. The system contains a main recirculation sump with vertical pumps. The blowdown pumps are separate from the pumps used for recirculation. This system works very much like a cooling tower basin. Makeup (service) water is added automatically as needed to keep a constant level in the sump. If additional water enters the system from the process, blowdown rates have to be increased to eliminate that water. Because makeup water is added automatically, the system can never go dry. Pumpout of excess water is handled manually. The pumps are located in a building right above the sump, so if excess water accumulates, it floods the area around the pump house. This does not occur often; however, by making frequent inspections, the operator is able to notice such a condition and activate the additional blowdown pumps. A biocide is added to this water to retard biological growth. Antifoulants and dispersants are also added to maintain water quality. System pH has never been a problem, although provisions were made to meter in sulfuric acid for pH control. Hydraulic balance is not a major concern because this is not a tight recycle system.

Water from the main sump is circulated to the gas cleaning equipment and flows by gravity back to a collection sump. This sump contains a pump suction screen with openings of approximately 1 in. to keep any large material out of the impellers. Vertical sump pumps (mostly Hazeltine pumps) are used at this point. The blast furnace sump pump has a rubber impeller that has been in operation for about 6 months with no sign of wear. Water is pumped from this sump to a splitter box, which also receives boilerhouse blowdown water (with a pH of 10 to 11) and other minor process flows. This steel splitter box is about 16 ft x 16 ft x 10 ft deep. The inlet water passes through a fairly coarse screen (approximately 1 in. openings). Most of the larger solids in the inlet water will settle out behind this screen. The splitter box has been cleaned once in the past 5 years. When last cleaned, about 5 ft of solids had collected in this inlet portion.

Wastewater flow to the splitter box varies according to the number of blast furnaces discharging to it. The flow per furnace is approximately 2000 gal/min. When four furnaces used to be in operation, the normal flow rate to the splitter box was 8000 gal/min.

Chemical Additions--

Chemical additions for scaling control have been discussed previously. In this section, polymer addition to aid sedimentation is discussed.

At Plant B, polymer is added in each of four splitter box chambers by a hose system. Iron pipe is used from the polymer mix and pump house to the perimeter of the splitter box and terminates in quick-disconnect hose fittings. The four 1-in. iron pipes are connected to 1-in. hoses that are draped across the top of the splitter box to reach each of the four clarifier feed sections of the box. At the end of each hose another quick-disconnect fitting connects to a "T." Pipes come from each side of the "T" to

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divide the polymer flow into four streams. Thus, four separate streams of polymer are dribbled into each clarifier feed section. The advantage of having the polymer drop openly through the grating of the splitter box down to the liquid level is that an operator can easily observe the addition of polymer in each section by walking on top of the splitter box.

Foaming problems had occurred in the splitter box when fuel oil was being fired in the blast furnace. Natural gas was being used during the visit, and such foaming was not a problem. Antifoam agents were added when the foam occurred, but did not work well. The cheapest and most effective solution for destroying the foam was to add water sprays to the inlet portion of the splitter box. The plant also discovered that the foam could be greatly reduced by improving the oil combustion. Solids concentration in the splitter box typically ranges between 100 and 200 ppm.

The polymer mix and pumping room contained two tanks and five Pulsa feeder pumps. One tank was used to store the polymer and the other tank was used as a combination mix and storage tank for diluted polymer. The four iron pipes going to the clarifiers came down one wall of the polymer house and terminated in a quick-disconnect fitting. The polymer feed pumps were connected to these lines via hoses. The advantage of using hoses here is that by touching the hoses and feeling the pulsation, the operator is able to determine whether the pump is operating. A Pulsa feeder pump identical to the polymer feed pumps is used to transfer polymer from the bulk polymer storage tank to the polymer mix tank. The plant supervisor noted that he had trouble at one time with a polymer that required aging before being fed to the clarifiers. This problem was solved by changing to a different polymer. Since changing polymers, he normally does not have any problems as a result of mixing and feeding the polymer in the same tank. Other polymer mix units in the same plant had two mix tanks so that polymer could be mixed and aged before being used.

At Plant A, the scrubber water is treated with an anionic polymer before it enters a splitter box. A cationic polymer is added into the splitter box before the water is split into two streams. Each stream goes to a thickener. A pipe with holes in it is used to distribute the polymer across the splitter box. The treatment chemicals used in the alkaline chlorination system are polymer, lime, and ferric chloride.

4.2.4 Effect of Upsets/Problems

Blast furnace recycle systems are generally stable. The major upsets that occur are related to flow balancing and sludge handling. The multiple clarifier/thickeners used tend to dampen minor chemical variations. The blast furnace operators must notify the treatment plant when a furnace is going down or on reduced wind because this changes the flow balance in the system. If water flow to the scrubber is reduced by the blast furnace operator, the cold well level will increase rapidly causing the automatic blowdown to increase. In systems where blowdown is used for slag quenching, the operators must either increase the recycle rate temporarily or increase blowdown to the outfall or blowdown treatment system holding tank.

Efficient removal of suspended solids is highly dependent on polymer dosage. If polymer is lost for as little as one hour (approximate system holding time), solids loading will increase from 20-30 ppm to perhaps as high as 100 ppm. It is important therefore for the operators to routinely check all elements of the polymer feed system at least once per shift.

Sludge density (percent solids) should be monitored at least once a shift to maintain a level that can be handled without creating excessive thickener rake torque and/or sludge pumping difficulties. The acceptable range at one plant is 15-20 percent. At another plant that dewaters the sludge, an operating range of 10-15 percent is used. Cake formation will be hindered during filtering if solids content is too low. If solids content is permitted to get too high, pumping difficulty may increase to the point that the thickener and sludge pumping system must be shut down for sludge removal. This would create a major outage for at least several days. An effective practice observed is the installation of flushing water lines in sludge piping to facilitate sludge flow during periods of high solids content.

Thickener rake torque is monitored and plotted by computer at one plant. At another plant, it is recorded three times per shift. Both plants have alarms on this parameter. Excessive torque can cause structural damage of sludge rakes, drive motors, and gearing mechanism. Repair of this equipment could require a system outage of a week or more.

4.2.5 Relationship Between O&M Practices, Upsets, and Effluent Quality

The major effluent parameters controlled for blast furnace wastewaters are:

- Suspended solids
- Oil and grease
- Ammonia
- Phenol
- Cyanide

Generally, oil and grease are not a cause of permit excursions in blast furnace systems. Where furnaces inject oil, occasional soot or oil carryover accumulates in the scrubber discharge. This can create foaming problems and the formation of black scum. This is usually handled effectively by the thickener/clarifier skimmers until the blast furnace operators adjust the oil injection/combustion at the furnace to eliminate carryover. Surfactant/polymer additions have proven successful when scum carryover is severe.

Several factors can cause suspended solids to increase:

- Loss of polymer or incorrect polymer feed
- Sludge buildup and carryover
- Hydraulic or thermal surges
- Hydraulic overload due to outage of a clarifier/thickener

As discussed previously, frequent monitoring and inspection is the primary O&M practice for avoiding such problems.

Several situations can lead to excursions when an alkaline chlorination system is used to reduce ammonia, phenol, and/or cyanide. The two general upset conditions leading to these excursions are inadequate oxidation of pollutants and formation of pollutant complexes or byproducts. A variety of O&M practices can lead to either type of excursion.

Excursions related to inadequate oxidation of pollutants are caused by a low-chlorine dosage of the wastewater and can easily be produced by any one of the following conditions:

- Failure of the chlorine injection system
- Use of injection water that exhibits a chlorine demand
- Increase in the chlorine demand of the waste
- Increase in the waste flow rate

Proper operating and maintenance practices within the alkaline chlorination area can prevent most of these upset conditions. An increase in the chlorine demand or waste flow rate is caused by the upstream systems. With the exception of the introduction of biological floc in the chlorination, any change of this nature (given adequate notification) can be accommodated in the chlorination system. Such upsets can be minimized, even without notification, if adequate influent and process monitoring is performed. Such upsets lead to increased levels of ammonia, phenol, and cyanide in the effluent.

The formation of pollutant complexes can occur when chlorination is performed on a cyanide-containing waste at a pH outside the acceptable range (see Section 3.8). Unacceptable byproducts are also formed with ammonia and phenol when the pH is outside acceptable ranges. The most common prevention is adequate pH monitoring at various stages of the chlorination treatment process. An even more dependable method is monitoring of free and total chlorine in the effluent. Free chlorine must be present for the chlorination process to be completed. In addition, the combined chlorine residual, i.e., the difference between total and free chlorine residuals, is comprised of the undesirable byproducts. Thus, a large combined residual can indicate operation outside appropriate pH ranges.

Table 4.2-2 summarizes some specific examples of excursions at blast furnace recycle systems and causes related to O&M practices. This information was extracted from noncompliance reports.

TABLE 4.2-2. EXAMPLE OF BLAST FURNACE WASTEWATER TREATMENT PERMIT EXCURSIONS

Cause of problem	Parameter/ pollutant exceeded	Date	Actual concentration, mg/liter	Allowable concentration, mg/liter
Maintenance procedure required flushing of cooling water lines at the blast furnace	Fe, SS			
Solids buildup in lagoon	SS	9/1/77		
Inadequate solids removal from blast furnace scrubber water treatment system	SS	3/82		
Excess caustic used for cyanide treatment	pH	4/82		
Problems with configuration of rakes in clarifier (Had to shut down for inspection)	TSS, CN, phenol, NH_3	10/81		
Samples collected during initial startup of treatment facilities	CN	8/81		
Problem with blast furnace recycle system clarifier	TSS, CN, phenol	9/81		
High ammonia levels in blast furnace coke	NH_3, kg/day	5/81	341	178
Hydraulic imbalance in recycle system when bringing furnace on line	TSS, kg/day	2/11	526	454
Blast furnace shut down	CN, kg/day	5/80	Up to 117	18
Frozen line caused slurry sump to overflow	SS			
Valve failure on thickener resulted in bypass	Not reported	4/81		
Partially plugged pipe resulted in overflows in blast furnace gas washer system	SS	6/15/79		
Overflow system imbalance due to thickener going on line	CN	9/14/79		
Upset in recycle system due to treatment chemical additive	CN	9/26/79		
Overflow from slurry sump	SS	4/1/80		

REFERENCES FOR SECTION 4.2

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2. Lichtner, F. W. Recycling BF Gas Scrubber Water Is an Rx for Pollution, but Can Create Other Woes. 33 Magazine, February 1980.

3. Turek, J. R., and D. E. Alton. New Technology For Blast Furnace Gas Cleaning Water Recirculation System. Iron and Steel Engineer, June 1980.

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5. Nemeth, R. L., and L. D. Wisniewski. Minimizing Recycled Water Blowdown From Blast Furnace and Gas Cleaning Systems. In: Proceedings of Symposium on Iron and Steel Pollution Abatement Technology for 1981, October 1981. EPA-600/9-82-021, December 1982.

6. Kohlman, H. J., and H. Hofstein. Minimizing Blowdowns From Selected Steel Plant Processes. In: Proceedings of Symposium on Iron and Steel Pollution Abatement Technology for 1981, October 1981. EPA-600/9-82-021, December 1982.

7. Becker, A. P., and T. M. Lachajczyk. Review of Water Usage in the Iron and Steel Industry: Blast Furnace and Hot Forming Subcategories. In: Proceedings of Symposium on Iron and Steel Pollution Abatement Technology for 1981, October 1981. EPA-600/9-82-021, December 1982.

8. Taming the Waters: Prepping H_2O for Coke Plant and BF Duty. 33 Magazine, February 1976. p. 34.

4.3 BASIC OXYGEN FURNACE (BOF)

A BOF shop typically has two furnaces. Each furnace has a separate scrubber, but both share a common water treatment system. All the BOF gas cleaning systems installed since 1973 have closed hoods (suppressed combustion) with scrubbers. The primary pollutant of concern is suspended solids. Since the water is recirculated, the concerns of dissolved solids and scaling are similar to those in blast furnace systems. The BOF systems do not have cooling towers; rather, cooling/evaporation takes place in the scrubber. Solids, largely calcium, are also dissolved by the scrubber water.

4.3.1 Arrangement of Treatment Components

The plant visits yielded information on only two BOF wastewater treatment systems. Three of the other five plants visited had BOF shops. One of these had a dry gas cleaning system, another had a semiwet system (the comparatively small amount of wastewater that was produced was combined with most of the plant's other wastewater streams), and the system at the third plant could not be studied because the environmental utilities personnel could not afford the time. As shown in Figures 4.3-1 and 4.3-2, the treatment components of the two systems studied are similar except that one system has recirculation (commonly practiced nowadays) and the other is a once-through system. Fewer details on operation were available on the latter system because tight scheduling prevented the operators from being available when the system was inspected. (The plant allowed the study of three other systems during which operating and environmental staff provided a significant amount of useful information.) Descriptions of the two BOF systems visited are provided.

First Plant--

Water containing dust from the scrubbers and operating area of the basic oxygen furnace is collected in sumps below the furnace area and then pumped to a splitter box in the wastewater treatment area. From the splitter box it flows to two degritters (small clarifiers that remove large solids that settle quickly). The degritters overflow to a 160-ft diameter clarifier. An older 135-ft diameter clarifier is used as an on-line spare. Polymer is added in the open trough that connects the degritters with the clarifiers.

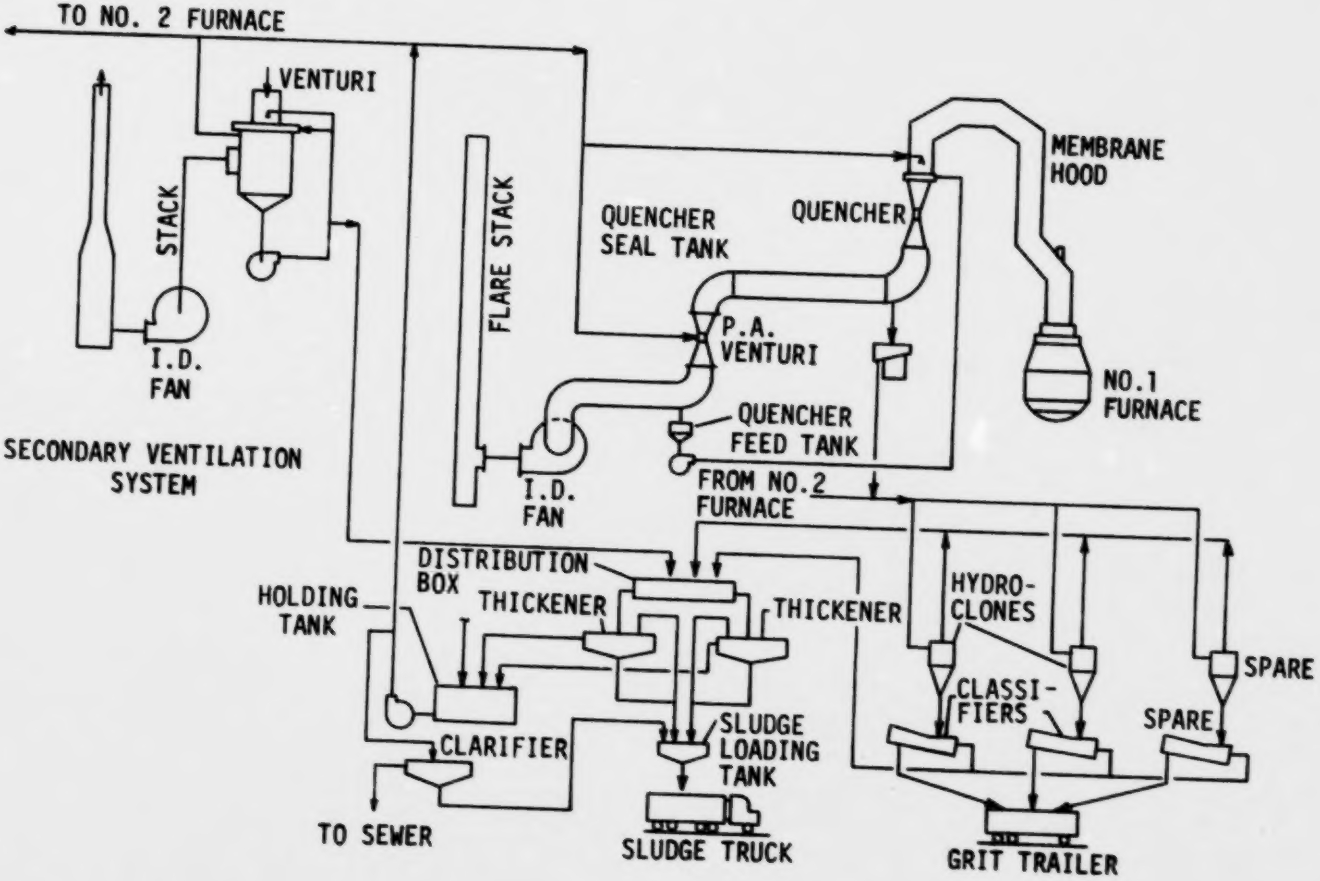
TO NO. 2 FURNACE
VENTURI
STACK
I.D. FAN
SECONDARY VENTILATION SYSTEM
FLARE STACK
I.D. FAN
QUENCHER SEAL TANK
QUENCHER
MEMBRANE HOOD
P.A. VENTURI
NO.1 FURNACE
QUENCHER FEED TANK
FROM NO.2 FURNACE
DISTRIBUTION BOX
HOLDING TANK
THICKENER
THICKENER
HYDRO-CLONES
SPARE
CLASSI-FIERS
SPARE
CLARIFIER
SLUDGE LOADING TANK
TO SEWER
SLUDGE TRUCK
GRIT TRAILER

Figure 4.3-1. BOF recirculation treatment system at a visited plant.

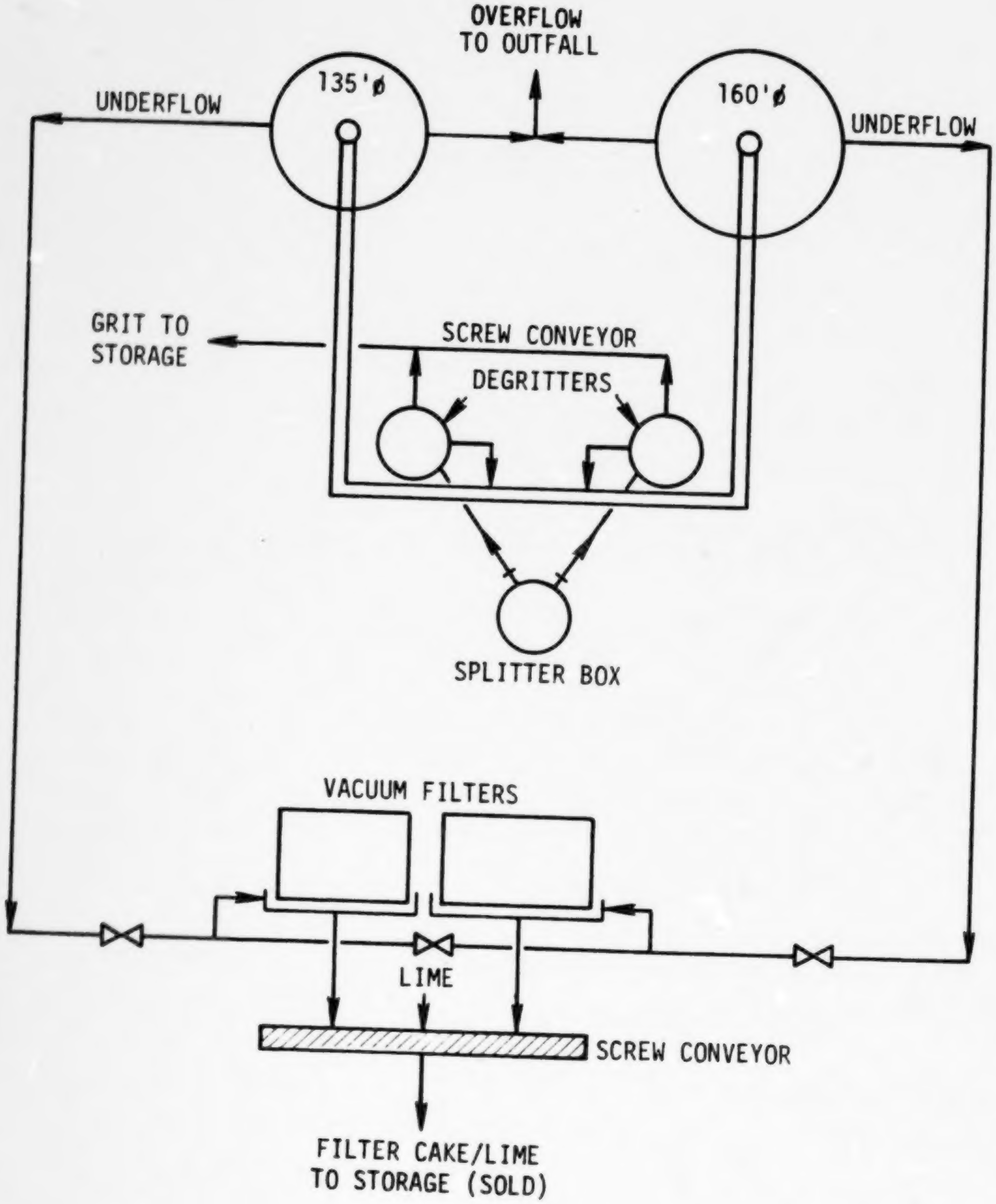
OVERFLOW TO OUTFALL
135'ø
160'ø
UNDERFLOW
UNDERFLOW
GRIT TO STORAGE
SCREW CONVEYOR
DEGRITTERS
SPLITTER BOX
VACUUM FILTERS
LIME
SCREW CONVEYOR
FILTER CAKE/LIME TO STORAGE (SOLD)

Figure 4.3-2. BOF once-through treatment system at a visited plant.

During the visit, the polymer addition concentration was 0.15 ppm. Water from the clarifier(s) is discharged to an outfall, as this is a once-through system.

Pinch valves were used on the lines carrying the wastewater because of abrasion problems. The pinch valves were installed by cutting out a section of the steel pipe and replacing it with a length of rubber pipe. A pair of rollers on each side of the rubber pipe section can be brought together, which squeezes the rubber pipe shut and closes off the flow.

The clarifier sludge pumps are installed in a building under the center of the clarifier. A tunnel is provided so a person can walk underneath the clarifier to the pump building. The pump suction lines are therefore very short and drop almost straight from the center of the clarifier to the pump inlet. This makes it easy to get to the pumps and suction piping for maintenance, and the shortness of the pipes and the vertical downward flow minimized sludge plugging problems. The pumps are Allen Sherman Hoff centrifugal sludge pumps with rubber-lined impellers and varidrives on the motors.

The sludge is pumped to two vacuum filters for dewatering. When the system was installed, recycle lines were put in so the sludge could be continuously pumped to the filter and back to the clarifier centerwell. The diameter of the recycle pipe was 10 inches. Unfortunately, the recycle operation had to be stopped because it increased the suspended solids in the clarifier overflow (up to ~100 ppm). The plant decided it was better to live with sludge lines that plugged periodically. When the budget permits, they plan to change to smaller sludge lines (e.g., 4-inch). They hope this will solve the problem by allowing them to recycle at lower rates.

The sludge is dewatered by drum filters on the second floor of the filter building. Two drum filters run continously on this sludge. The filter building houses four drum filters, two for the BOF and two for dewatering sludge from the blast furnace thickener. The plant has had success with these filters. The filters are mounted on the second floor of the building so the cake can drop into a bin below. This bin feeds a pug mill, where the sludge is mixed with fly ash, cement, or lime and sold as a subgrade material.

The drum filters have a continuous cloth seal arrangement on the top of the filter (drying section of the drum). This cloth is pressed against the cake to prevent air leaks through cracks in the cake. This reduces the chance of vacuum loss and allows the filter to produce a drier cake.

Second Plant--

Process wastewater from the suppressed-combustion BOF's is generated by the gas quencher and venturi scrubber. When gas from the BOF is quenched, the dirty water is discharged into a quencher seal tank and the gas goes on to the venturi scrubber. The scrubber water goes into a quencher feed tank and then cascades to the quencher. Quencher water goes into a cyclone head tank in the treatment area, which feeds three cyclone separators (one is kept as a spare). The cyclones discharge into a common header, which ties into a splitter box that feeds two 100-ft diameter thickeners. (Fugitive emissions are vented to a scrubber system, and discharge from this variable-flow system also goes into the splitter box.) Clarified water goes into a hold tank and is pumped back to the venturi scrubber. A portion of this water also goes to the quencher. Blowdown water is discharged to a terminal treatment plant.

Functions of BOF Components--

Components of most of the BOF wastewater systems were described in detail in Section 3; however, their functions are again described briefly here.

Primary solids removal--The first solids removal step is generally accomplished either with a classifier or bowl desiltor (degritter).[1] This discussion is limited to the classifier. A classifier (illustrated in Figure 4.3-3) consists of a hydraulic cyclone mounted above an open, inclined screw conveyor. Its function is to remove the larger particles of suspended solids. The centrifugal force causes the heavy particles to move to the outside and settle. From the classifier they exit into a screw conveyor. Lighter particles move into the vortex and overflow out the top of the cyclone with the main stream of water. Dirty water overflows at the lower end of the screw conveyor trough and is piped to the thickener.

Construction and operation of this type of classifier are very simple; the hydraulic cyclone is simply a tank lined with rubber or some other abrasion-resistant material, and the screw conveyor is of standard design.

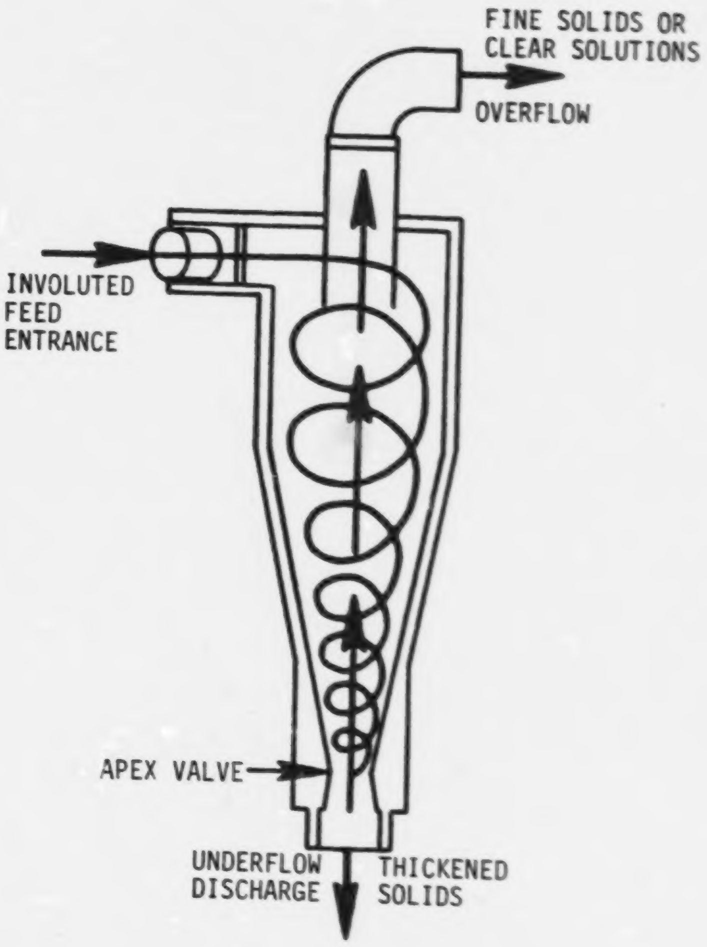
FINE SOLIDS OR
CLEAR SOLUTIONS
OVERFLOW
INVOLUTED
FEED
ENTRANCE
APEX VALVE
UNDERFLOW
DISCHARGE
THICKENED
SOLIDS

Figure 4.3-3. Illustration of a classifier.

Courtesy of Iron Age. Improving Efficiency of BOF Scrubber Systems. September 6, 1982.

The only moving part is the screw itself. The use of a classifier does require some additional head in the slurry line from the scrubber to the thickener because the water from the bottom of the inclined screw conveyor must flow by gravity to the thickener.

Distribution box--Water overflowing the classifier is piped to a distribution or splitter box ahead of the thickeners. The function of the distribution box is to collect various flows, such as scrubbing water, filtrate returns, and sump drains, and to distribute them evenly to the thickeners. Its location is ideal for adding a coagulant aid or other additives, as it permits some reaction time before the water actually enters the thickener.

Thickener--This piece of equipment has a dual function and can rightly be called a clarifier/thickener. It allows most of the particles to settle out of the water (clarifies it) so it can be recirculated. It also "thickens" the particles into a concentrated slurry for discharge to vacuum filters, centrifuges, or settling lagoons.

Both plants visited had dual thickeners, which permitted continued operation of the BOF shop during a thickener outage.

Vacuum filter/centrifuge--Because of the fine particle size of BOF dust, a drum-belt vacuum filter is normally used for this service. Use of the proper filter cloth is important to obtain the most effective filter performance. Usually a matter of experience and judgment, selection is based on the particle size range in the particular slurry, the temperatures under which the belt must operate, the need for a stable filter material to avoid shrinking or stretching, the wear properties of the cloth, etc.

An alternative to drum-belt filters that has been used at several steel plants is a solid-bowl, scroll-discharge centrifuge. As was shown in the cross section in Figure 3.4-3, the slurry is fed into one end of the centrifuge and the solids are thrown against the wall of the rotating bowl by centrifugal force. The internal screw or scroll rotates at a slightly lower speed than the bowl and moves the solids to the discharge end.

Blowdown--Blowdown is required because the water evaporated and carried off by the gas leaves behind all of its dissolved solids. At the same time, the scrubbing water picks up and dissolves some of the solids in the gas stream, particularly lime and fluorides. As more and more evaporation takes place, dissolved solids reach a maximum desired concentration. When this occurs, the excess amounts are removed by blowing down part of the concentration solution.

4.3.2 Identification of Major Areas of O&M Concern

Focus in this section is primarily on BOF systems that have recycle loops because many plants have recirculation systems. Also, this technology is emphasized in the guidelines for steel mill effluent limitations.

This section is brief for two reasons: 1) only one BOF system with recirculation was studied, and 2) most of the major areas of concern for BOF's (e.g., scaling potential, solids handling, maintenance of chemical additions) are discussed extensively in the blast furnace section (Section 4.2). Operation and maintenance practices for components that are used to treat BOF wastewater are discussed in Section 3; therefore, this section presents only specific O&M information obtained from BOF treatment operators at the visited plant.

The major areas of O&M concern addressed here are as follows:

- Control of dissolved solids
- Control of pH
- Control of suspended solids
- Maintaining sludge removal from thickeners/clarifiers at proper rate to avoid thickener upsets and/or rake damage

Control of Dissolved Solids--

The water problems most commonly associated with a BOF include the formation of scale and corrosion products in the gas scrubber system and other areas (e.g., lance and hood cooling systems).[1] The scrubbing water collects salts during the BOF gas cleaning stage. Because a significant fraction of the dust removed from the furnace gas is calcium and magnesium (from the lime flux added to the BOF), oxides of these compounds can react with the dissolved carbon dioxide in the wastewater to form the carbonates, which pose potential scaling and fouling problems.[2] The scaling potential increases significantly with tight recycle loops, as the water recirculates numerous times (referred to as cycles of concentration). If dissolved solids treatment and the amount of blowdown are not properly controlled, plugging problems can occur. One study reports that the recirculated water at one plant contained such high levels of alkalinity from increased carbonate concentrations (1680 mg/liter) and hardness (1700 mg/liter) that it caused severe scaling problems in pumps, piping, and spray nozzles.[2] The mechanical foreman at another plant was quoted as saying that because of the severe effects of scaling, "It took six employees, working 16-hour shifts, six days to clean out the duct area at the bull nozzle."[1]

Control of pH--

Control of pH of the recirculating water is important for two reasons. First, as the cycles of concentration increase, the concentration of the calcium and magnesium carbonates in the water also increases and causes the alkalinity or pH of the wastewater to increase. The increasing carbonate concentration, along with higher pH, causes salt precipitation (scaling). Many plants add sulfuric acid to the system to lower the pH and help keep the salts in the dissolved state.

The second reason is that that control of discharged water pH is important, particularly if the water goes to an outfall where the maximum allowable pH is 9. Lack of proper control of the pH of the blowdown going to an outfall could likely result in numerous permit excursions.

Control of Suspended Solids--

The primary purpose of a BOF wastewater treatment system is to remove the solids from the water used to clean and quench the BOF offgas stream. Optimum control and removal of suspended solids is required at each component step (e.g., classifier, thickener, vacuum filter, blowdown treatment) to maximize recirculated and discharged water quality. Failure to control suspended solids can ultimately cause process problems that can result in shutdowns and cause degradation of receiving streams (rivers, lakes, etc.).

Maintaining Sludge Handling Equipment--

Considering the large amounts of solids removed from the BOF offgas by scrubbers and then collected in cyclones/desilters and thickeners, the importance of ensuring that the sludge handling equipment is maintained in good working order is obvious. Overaccumulation of sludge can quickly cause plugging in pipes, pumps, and all equipment where the solids accumulate.

4.3.3 Identification of Effective O&M Practices

Control of Dissolved Solids--

Dissolved solids can be controlled by pH control, balanced schedule of blowdown and makeup, and chemical treatment. Two or sometimes all three are usually used in conjunction with each other.

The dissolving capability of recirculated water can be improved by maintaining a desired pH range. The visited plant that practiced recycling used to add sulfuric acid to the recirculating water to maintain a desired pH level of 7 to 9. (This plant now discharges to a terminal treatment plant.) The pH was monitored continuously from a bleed line off the venturi pump discharge line. When the pH rose to 8.8, the controller sent a signal to start the acid metering pump. The automatic system stopped the pump when the pH reached 7. A higher than desired pH signaled an alarm to go off on the control panel. Periodic inspections of the acid system and pH sampling/ analysis are effective practices for backing up the automatic system, particularly since pH probes can foul easily. (Regular cleaning of the probes is also an effective and necessary practice.) The acid metering pump was adjusted manually at a desired pumping rate. Periodic inspection and regulation of the pump rate are required for effective pH control.

Blowdown is necessary on essentially all recycle systems that have scaling potential. It allows a portion of the highly concentrated dissolved solids in the wastewater to be purged and makeup water (with much lower dissolved solids concentration) to be added so that the overall concentration will be lower than the saturation point to avoid salt precipitation.

Plants have their own criteria to determine how much blowdown is discharged. This depends on scaling potential of their system (which depends on things such as BOF operation, amount of lime in flux, constituents of flux, efficiency of the scrubber, water temperature). The plant visited uses several parameters as criteria for blowdown. The operating supervisor said that the upper limits for hardness and conductivity are 200 mg/liter and 600 mg/liter, respectively. Maximum pH allowed is 10.5 (this is fairly high, but the supervisor said it aids in thickener flocculation). Blowdown rate is also adjusted if iron and zinc concentrations become too high. This would probably be done to avoid potential permit excursions.

Chemical Treatment--

Chemical treatment is extensively used in the iron and steel industry for application such as coagulants in clarifiers/thickeners, flocculant aids, sludge dewatering aids, and scale inhibitor. Addition of these chemicals at optimum dosage rates is an effective operating practice. (Section 3.7 contains more details on the addition systems and recommended dosage ranges for various steel mill wastewater applications.)

A recent article describes a successful application of a new scale deposit inhibitor that has replaced the acid feed system. The treatment agent is a liquid organic scale inhibitor and polymeric dispersant (it is called CL-165 and is manufactured by Calgon).[1] The inhibitor is fed into the return ahead of the venturi pump at a concentration of 5 to 10 mg/liter. Effective scale inhibitors are being used at a number of steel mills to facilitate wastewater recycle systems. Other effective operating and maintenance practices are required such as inspecting and monitoring the chemical additive system to see if the flow and dosage rates are adequate. Because of the dependency of the treatment chemicals, quick maintenance action is required if a polymer system breaks down and becomes plugged.

Control of pH--

Maintaining pH levels to help control dissolved solids is discussed above. Effluent or discharge pH is also important to control because lack of it can cause downstream problems (e.g., permit excursions). Most permits limit outfall pH from 6 to 9; therefore, operators and/or environmental department personnel should take samples at least daily to calibrate or verify the accuracy of pH meters.

Control of Solids/Sludge--

At the plant with recycle, the following O&M practices are implemented:

- Cyclones and classifiers are inspected each shift for proper operation. The cyclones are lined with 3/8 in. rubber. The lining is periodically replaced. Time is required to pull out the lining, clean the cyclones, then reglue new liner strips tightly together. At one occurrence the rubber lining was not stocked in the storehouse and the cyclone was put in operation while the rubber was being ordered. Pinhole leaks in the cyclone developed in three days due to the severe abrasiveness.

- Classifiers are maintained as needed by the plant's water pollution control maintenance department. Classifiers need to be replaced every 2 to 3 years. A working spare is available. A thorough inspection of the classifiers is performed monthly.

- Thickeners are drained about once a year for thorough inspection.

- Sludge pumps are visually inspected each shift during the operator's rounds. Diaphragms in the sludge pumps must be replaced periodically. They can usually be replaced within half an hour.

- There are three polymer companies that service the plant. The one responsible for the BOF thickener polymer addition performs periodic tests to try to ensure that the optimum dosage rate is met. The polymer representative works closely with the operators. He periodically bench tests new polymers. Operators also perform periodic bench tests to see if they are in agreement. The operator must also check the chemical storage tanks for inventory, mix fresh batches of solution as required, check the area for leaks, and check the chemical delivery point for actual flows.

- Percent solids of the thickener sludge is maintained at approximately 25 percent. When slurry is not loaded into tank trucks, it is recirculated to the thickeners to act as seed material, which promotes solids settling. Sludge recirculation also helps minimize plugging in sludge pipes. The thickener underflow rate is approximately 90 gpm. (The thickener inlet flow is about 3000 gpm. Thickener capacity is approximately 650,000 gallons each.)

- The thickeners are equipped with automatic rake lifting devices if torque becomes too great. The operators also monitor and record torque. Above normal torque readings are immediately called to the supervisor's attention and troubleshooting action is initiated. High torque alarms also sound in the control room.

- All sludge pumps have on-line spares.

Other Effective O&M Practices--

- One well-trained operator is in charge of the BOF treatment system each shift. On day turns, he also has a helper who is primarily in charge of sludge loading.

- The utility operator performs frequent inspections and logs important data. (An example form based on some of the required monitoring and sampling is shown in Figure 4.3-4).

- There has also been a good communication link between the utility operators, process operators, supervisors, and environmental personnel.

Date:

Operator's name:

Parameter	No. 1 thickener	No. 2 thickener	Venturi
Torque			--
Sludge density			--
Sludge removal, gal			--
pH			
Hardness			
Conductivity			

System blowdown, gpm:

Figure 4.3-4. BOF gas cleaning treatment system - daily report.

4.3.4 Effect of Upsets/Problems

Process or wastewater treatment upsets and problems as described in other similar sections have varied effects on downstream treatment components. If the classifiers or degritters at the visited plants become plugged or if a rubber liner on a cyclone gets torn, the problem will be discovered by the frequent operator and maintenance inspections and the spare equipment will be put into operation until the problem is solved. The effect of this kind of problem will be minimal as long as it is detected early.

Plugging of wastewater lines due to scaling (e.g., due to extended scale inhibitor or acid feed pump outage) could be serious to the scrubber system or anywhere in the wastewater treatment loop.

Failure to properly remove solids in thickeners before they become too dense could also cause downstream problems. This could arise if sludge pumps would malfunction (and spares were not maintained) or if there was an extended power outage with no backup power supply to operate the pumps. One plant said that they would have thickener torque problems if the percent solids of the sludge exceeded 35 percent. Thickener outages can last for hours or days depending on the problems. An extended outage would cause considerable additional hydraulic loading on the other clarifier(s); this would decrease solids retention and could cause greatly increased concentrations of suspended solids to be discharged from the thickener. If the thickener discharges to an outfall, there could easily be some total suspended solids (TSS) violations; if it discharges to a clarifier, that component could be upset and lead to permit violations; if it discharges to a terminal treatment plant, the plant's capacity may or may not be adequate to handle the additional load.

In summary, the effects of upsets and problems depend on the specific plant and situation. If processes and related wastewater equipment are at maximum operation then small upsets, such as with hydraulics, could cause a significant downstream problem. During the very low production times currently being experienced, lower wastewater flows from some processes allow treatment components to be operated with considerable surge capacity. Hydraulic and other upsets under these conditions can more easily be "absorbed" and cause little effect downstream.

4.3.5 Relationship Between O&M Practices, Upsets, and Effluent Quality

Failure to perform any of the following such O&M practices could lead to poor effluent quality:

- Check polymer system to see if polymer is discharging and at proper pump rate.
- Take pH samples and verify and/or calibrate pH meter.
- Keep spare equipment in good working order.
- Maintain a log of important parameters, which should be inspected by the supervisor.
- Maintain a stock of important parts.
- Take followup action when upsets occur.
- Ensure that operators do not depend too heavily on instrumentation and "lighten up" on their inspections.

Table 4.3-1 shows specific examples of excursions from BOF wastewater, some of which are related to the lack of O&M practices.

REFERENCES FOR SECTION 4.3

1. Iron Age. Improving Efficiency of BOF Scrubber Systems. September 6, 1982.

2. Wong-Chong, G. M., and S. C. Caruso. An Evaluation of the Treatment and Control Technology Recommended for the Basic Oxygen Furnace (BOF) Wastewaters. Water Resources Project. Carnegie-Mellon Institute of Research, Pittsburgh, Pennsylvania 15213. May 1977.

TABLE 4.3-1. EXAMPLES OF BOF WASTEWATER PERMIT VIOLATIONS

Cause of problem	Parameter/ pollutant exceeded	Date	Actual concentration	Allowable concentration
Abnormal increase in H_2SO_4 addition for pH adjustment at BOF treatment	pH	3/30/81	9.2	9 (max)
Sampling problems at BOF thickener. Nonrepresentative samples	TSS pH	5/80		
Leak in acid feed line for pH control at BOF recycle system	pH	7/9/81	9.1	9 (max)
Operator error at BOF system	SS, mg/liter	7/25/81	34	30
Fluctuation in blowdown pH and flow from BOF gas cleaning system	pH	4/15/81	9.2	9 (max)
Sampling problem at BOF thickener	TSS pH	8/80		

4.4 HOT FORMING

As discussed in Section 2.4, hot forming is a category that includes numerous rolling and forming operations. Its major subdivisions include primary mills (producing blooms, slabs), section mills (producing billets or direct finished products such as rails and I-beams), flat mills (producing plates, hot strip, sheet), and pipe and tube mills. Treatment technologies in use at these operations are basically the same and primarily include the following basic treatment units: primary sedimentation, surface oil removal, secondary settling or filtration, and recycle.[1] More than 96 percent of all hot forming operations have primary scale pits to collect and recover the heavier suspended solids and to allow the tramp oils to float to the surface for skimming.[1] Because the treatment technologies for all hot forming operations are basically the same and because all of the plants visited allowed their hot strip mill (HSM) systems to be inspected, the following subsections will primarily discuss treatment systems for HSM wastewater.

4.4.1 Arrangement of Treatment Components

There are numerous arrangements of treatment components comprising the systems for treating wastewater from hot forming operations.[1] Of the HSM treatment systems visited during this study, all had scale pits for primary treatment. The various subsequent treatment components at the four plants are shown below:

Plant 1: Deep-bed pressure filters (multimedia)
Plant 2: Clarifiers, settling basins
Plant 3: Settling ponds
Plant 4: Gravity filters (multimedia)
Plant 5: Settling lagoons, deep-bed sand filters (see Figure 3.8-3)

Schematics showing these component arrangements are shown in Figures 4.4-1 through 4.4-4. Figure 4.4-5 shows the slab caster/slab mill treatment system for Plant 3.

4.4.2 Identification of Major Areas of O&M Concern

The following are the major areas of O&M concern for hot forming (primarily based on hot strip mill) wastewater treatment systems.

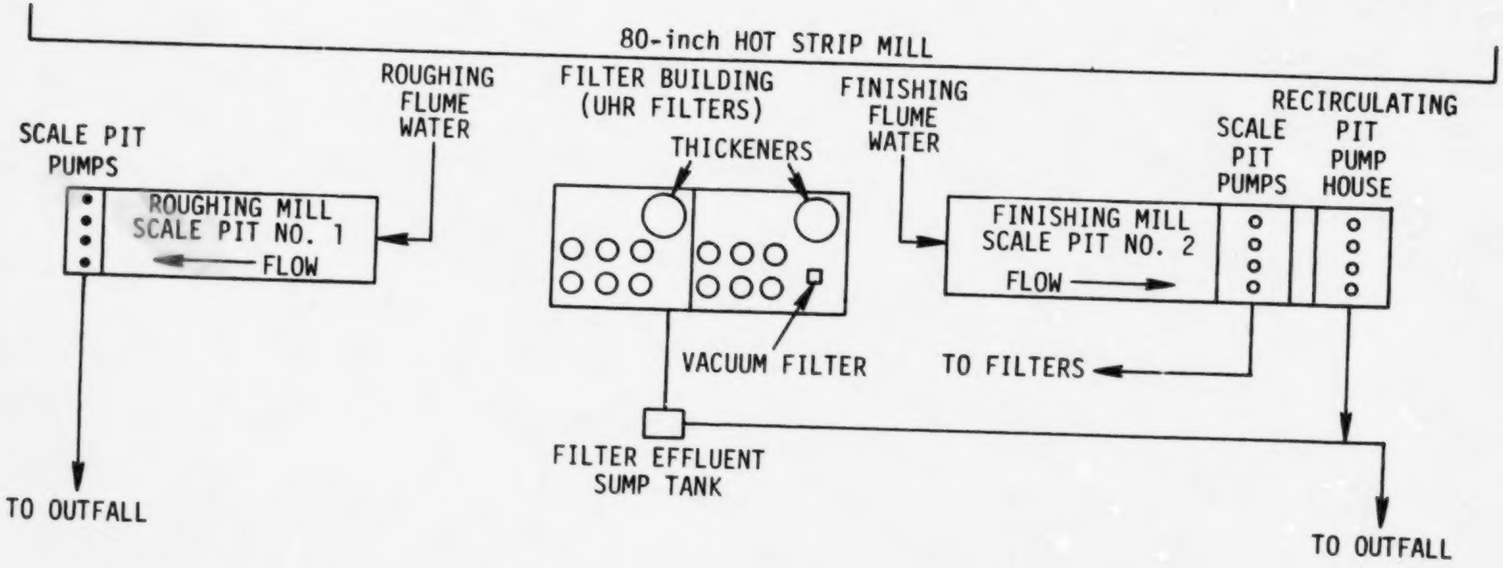
80-inch HOT STRIP MILL
ROUGHING FLUME WATER
FILTER BUILDING (UHR FILTERS)
FINISHING FLUME WATER
RECIRCULATING PIT PUMP HOUSE
SCALE PIT PUMPS
THICKENERS
ROUGHING MILL SCALE PIT NO. 1
FLOW
FINISHING MILL SCALE PIT NO. 2
FLOW
SCALE PIT PUMPS
VACUUM FILTER
TO FILTERS
FILTER EFFLUENT SUMP TANK
TO OUTFALL
TO OUTFALL

Figure 4.4-1. Hot strip mill treatment showing deep-bed pressure filters at Plant 1.

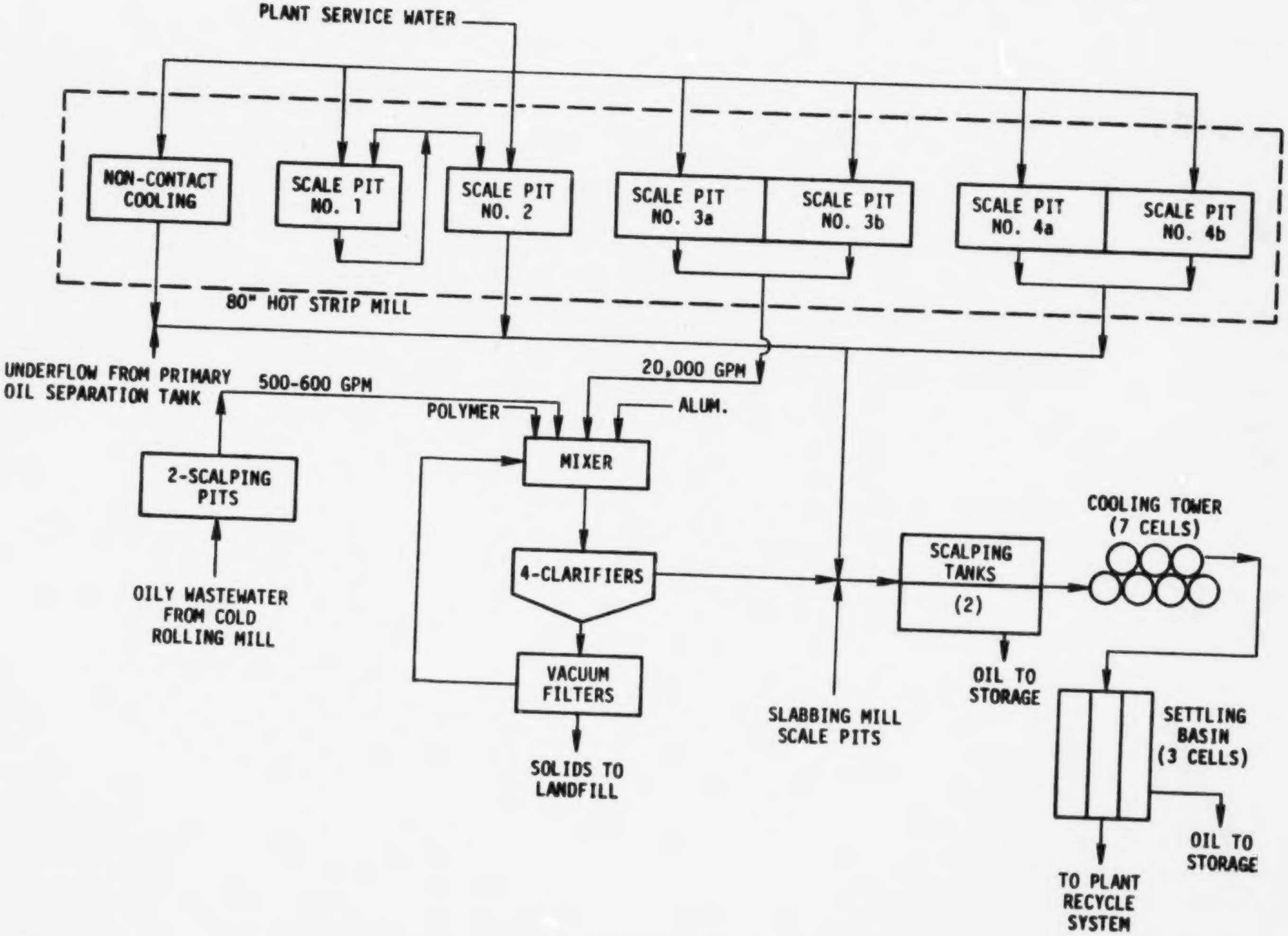
PLANT SERVICE WATER
NON-CONTACT COOLING
SCALE PIT NO. 1
SCALE PIT NO. 2
SCALE PIT NO. 3a
SCALE PIT NO. 3b
SCALE PIT NO. 4a
SCALE PIT NO. 4b
80" HOT STRIP MILL
UNDERFLOW FROM PRIMARY OIL SEPARATION TANK
500-600 GPM
20,000 GPM
POLYMER
ALUM.
MIXER
2-SCALPING PITS
OILY WASTEWATER FROM COLD ROLLING MILL
4-CLARIFIERS
VACUUM FILTERS
SOLIDS TO LANDFILL
SLABBING MILL SCALE PITS
SCALPING TANKS (2)
OIL TO STORAGE
COOLING TOWER (7 CELLS)
SETTLING BASIN (3 CELLS)
OIL TO STORAGE
TO PLANT RECYCLE SYSTEM

Figure 4.4-2. Hot strip mill, cold rolling mill, and slabbing mill treatment system at Plant 2.

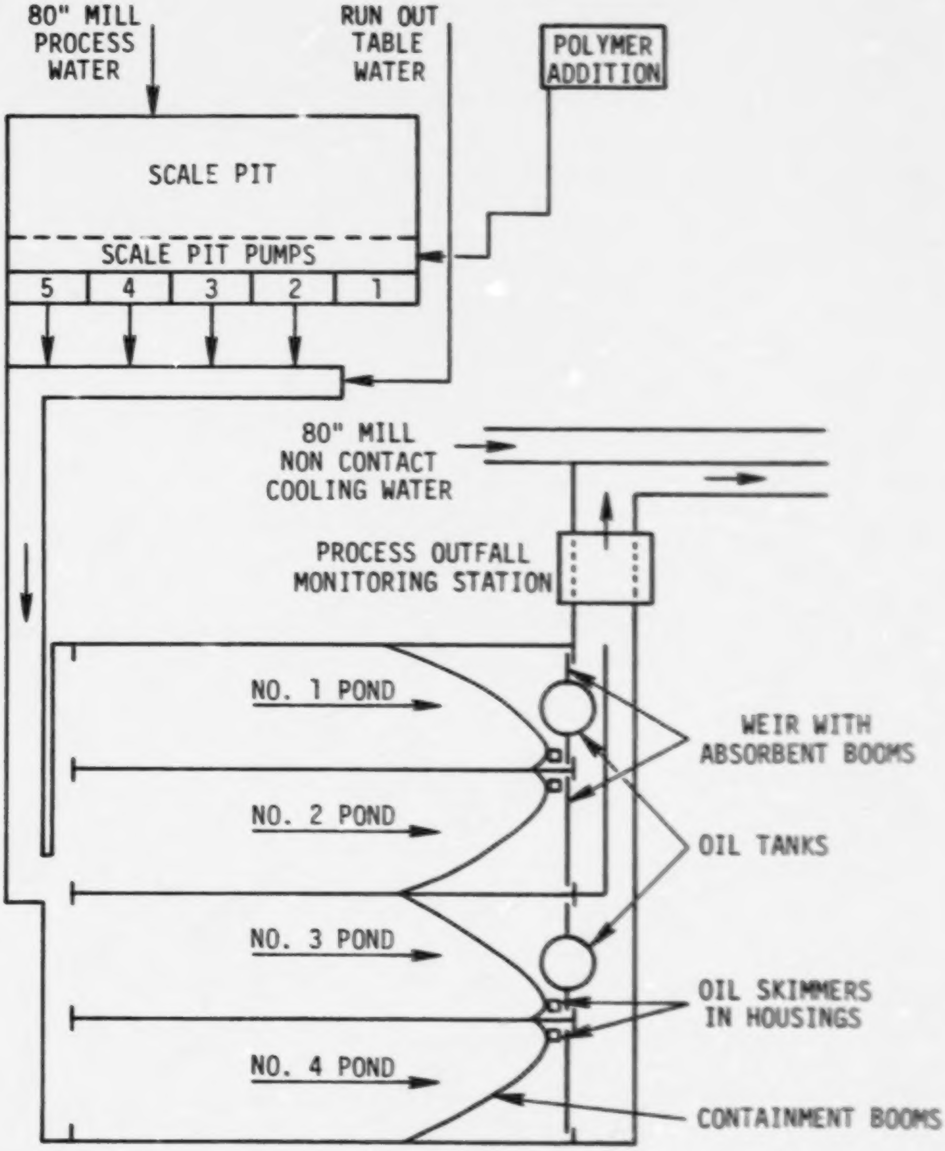
80" MILL PROCESS WATER
RUN OUT TABLE WATER
POLYMER ADDITION
SCALE PIT
SCALE PIT PUMPS
5
4
3
2
1
80" MILL NON CONTACT COOLING WATER
PROCESS OUTFALL MONITORING STATION
NO. 1 POND
NO. 2 POND
NO. 3 POND
NO. 4 POND
WEIR WITH ABSORBENT BOOMS
OIL TANKS
OIL SKIMMERS IN HOUSINGS
CONTAINMENT BOOMS

Figure 4.4-3. Hot strip mill treatment showing settling ponds at Plant 3.

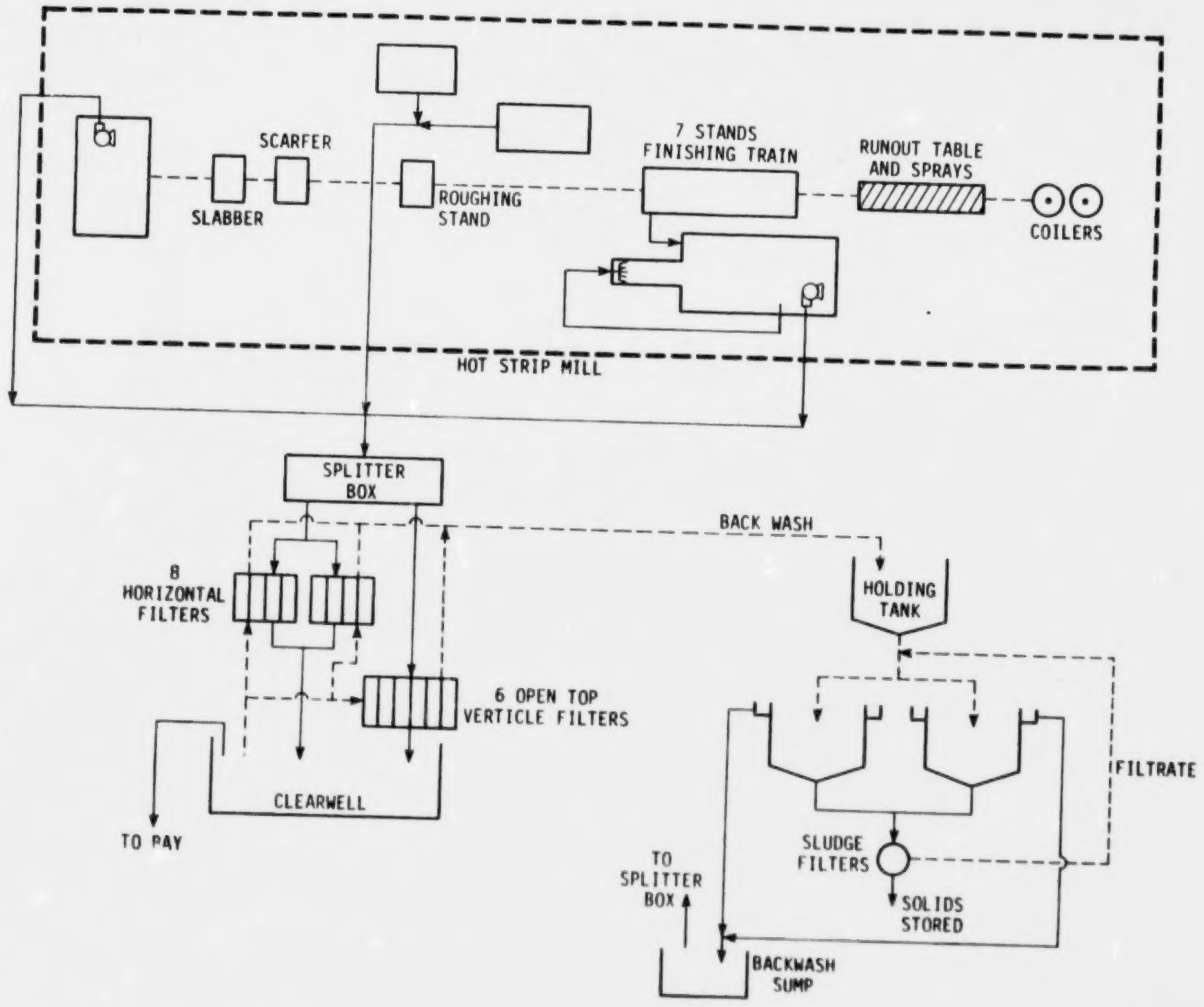
SCARFER
SLABBER
ROUGHING STAND
7 STANDS FINISHING TRAIN
RUNOUT TABLE AND SPRAYS
COILERS
HOT STRIP MILL
SPLITTER BOX
BACK WASH
8 HORIZONTAL FILTERS
6 OPEN TOP VERTICLE FILTERS
HOLDING TANK
CLEARWELL
TO PAY
FILTRATE
SLUDGE FILTERS
TO SPLITTER BOX
SOLIDS STORED
BACKWASH SUMP

Figure 4.4-4. Hot strip mill treatment showing gravity filters at Plant 4.

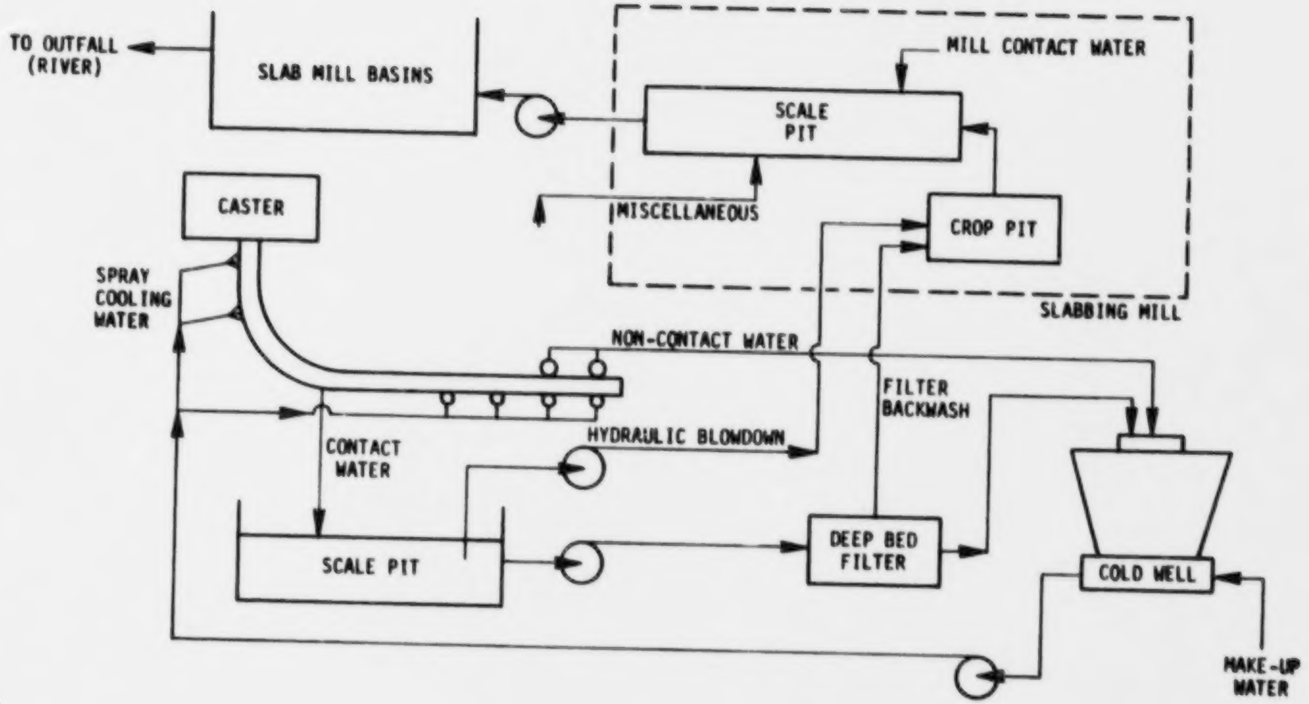
TO OUTFALL (RIVER)
SLAB MILL BASINS
MILL CONTACT WATER
SCALE PIT
CASTER
MISCELLANEOUS
CROP PIT
SPRAY COOLING WATER
SLABBING MILL
NON-CONTACT WATER
FILTER BACKWASH
CONTACT WATER
HYDRAULIC BLOWDOWN
DEEP BED FILTER
SCALE PIT
COLD WELL
MAKE-UP WATER

Figure 4.4-5. Combined wastewater flow and treatment diagram for slab caster and slabbing mill at Plant 3.

- Scale pit operation
- Communication
- Sludge handling
- Chemical treatment
- Filter backwashing
- Operator and maintenance attention/inspections/monitoring of key parameters

Scale Pit Operation--

Essentially all hot strip mills (HSM) utilize scale pits to receive flume flush water. This water carries scale (and lubricating oils) generated at the mill stands during the roughing and finishing operations (see Section 2.5). At four of the five plants visited, the HSM scale pits are operated by the HSM operators rather than the utilities department, who is responsible for the general operation of the plant's wastewater treatment equipment. It is important that scale pits are well-operated for the following reasons:

- Many scale pits servicing scale breakers and initial roughing stands, where large scale particles are collected, discharge directly to an outfall. Therefore, operation of the scale pits (particulary a one-pit operation) has a significant impact on effluent (outfall) water quality.
- Other scale pits, whose normal discharge of suspended solids cannot meet outfall limits, are followed by secondary pollution control equipment such as clarifiers, lagoons, and/or filters. Therefore, operation of the scale pits is a concern because the discharge loading directly impacts the subsequent treatment components.
- Scale pit/secondary system discharge water is recycled for reuse back to the HSM. Again, operation of the scale pits can greatly affect the discharge water quality, which can adversely impact the operations that receive the recirculated stream (e.g., strip cooling).

Because scale pits are gravity settling chambers that are relatively simple in design, operation of the pits is not complex. However, perhaps because of their simplicity and a misunderstanding by mill personnel that the scale pits are primary pollution control components, their operation as pollution control equipment may be overlooked. This is oftentimes true because the HSM operators (who have different perspectives of scale pits than do the utilities personnel) usually are responsible for the operation of the scale pits. Without surveying the entire iron and steel industry, it seems probable that most HSM operators do not think of solids and oil concentrations fluctuating at the inlet and outlet of scale pits and that these concentrations are affected by mill operations and scale pit operations (e.g., changing flows to the pits, clam shelling, oil removal). At one minute the pit influent may contain less than 100 mg/liter of solids, and then shortly it can contain more than 2000 mg/liter.[1] Average influent oil concentrations are usually about 10 to 30 mg/liter, but can be 100 mg/liter or more following incidents of oil spills, line breaks, excessive dripping of lubricants, or discharge of oils and greases during equipment washdowns.[1]

The operators need to be aware of the fluctuating conditions and pit retention time (affected by scale buildup) and how they affect scale pit discharge water quality.

Communication--

As in the coke byproduct plant and biological treatment system, proper communication is a major concern because operators of the scale pits and secondary pollution components are usually in different departments. During the plant visits, the utilities personnel apparently knew very little about operations and changing conditions at the HSM and scale pits. Proper communication could help improve the utility operator's understanding of adverse conditions that are occurring at the mill/scale pits so that he can take actions to minimize the effects on his treatment components.

Sludge Handling--

This is an area of concern because of the great quantity of solids that has to be handled and the problems that can occur in moving and filtering the abrasive sludge. (Settled scale from scale pits is not considered here. It is clamshelled or removed by travelling grates into bins or railcars and usually transported to a sinter plant or stockpiled and sold to other plants for sinter feed.)

If sludge is not handled properly (it should be pumped, removed from the treatment components, filtered, and disposed of), a multitude of problems, such as line and equipment plugging, equipment breakdowns, decreased retention times, etc., probably will result. Any of the problems can cause a degradation in the quality of water discharged from the affected treatment components.

Chemical Treatment--

Various polymer and other treatment chemicals are used at the plants visited. Two of the plants whose HSM scale pits discharged to large settling ponds did not use polymer. One plant with clarifiers uses a polymer at a tank where HSM wastewater (~30,000 gpm) and cold strip mill wastewater (~500 gpm) are mixed. Another plant adds polymer to their backwash thickener underflow to promote good solids separation in the centrifuge. A plant having problems with cake formation on their vacuum filter plans to experiment with chemical addition. Maximum settling of solids in clarifiers can be ensured by introducing a combination of cationic and anionic polymers and maintaining good pH control.[2] For those plants that depend on chemical treatment, maintenance of proper dosage rates is a concern. Inadequate O&M practices would allow a malfunctioning chemical feed system to go unnoticed until an obvious problem occurred such as increased clarifier turbidity/suspended solids concentration or formation of a thin vacuum filter cake. Inadequate dosage rates would also lead to an increased number of backwash cycles for plants using deep-bed filters.

Filter Backwashing--

A number of steel mills use gravity and pressure filters for treatment of hot forming wastewaters. Several filters were installed at the plants visited to remove solids from hot strip mill and slab caster discharge waters. Periodic backwashing of the filter media is important to maximize filter efficiency and minimize problems that can result from a plugged filter bed. Effective operation of the filters is the desired goal, but this can be accomplished by effective periodic cleaning or backwashing of the media. Articles specifically addressing the effectiveness of backwashing and optimum backwashing are available in the literature.[3,4]

One article specifically addressing rolling mill effluent filtration provides the following information on backwashing: backwash rates will vary between 15 and 40 gpm/ft^2; backwash volumes should be approximately 5 percent of influent flow; backwash duration will normally be 5 to 10 minutes; and air scour is applied for 3 to 5 minutes at 6 to 8 cfm/ft^2 of filtration area.[5]

As noted in another reference though, "Regardless what the engineer designs, the backwash rate for the operation is in the hands of operators who, being pragmatists, hold to the belief that theoretical figures only have value in terms of their practical applications. They will finally decide on the optimum rate of backwash."[4] This statement has meaning at one steel mill visited that utilized pressure filters. The operators did not adjust the backwashing flow rate, but did vary the backwash air scour and flushing durations in efforts to optimize their system. The point made is that backwashing affects filter performance, and effective backwashing depends in part on effective O&M practices.

Operator and Maintenance Attention Inspections/Monitoring of Key Parameters--

The overall theme of this study is that no matter how well a system is designed, effective O&M practices are necessary for optimum operation and performance of the systems. In general, the HSM treatment systems visited were well operated. Varying degrees of operator attention were given depending on the types of treatment components installed and the degree of automation employed. The two plants with settling ponds required an operator to only inspect the ponds and oil skimming equipment a couple of times per shift. One plant with a deep-bed pressure filter on manual control required an operator to continuously man his station and to perform operating functions frequently. He adjusted flows to the filters depending on scale pit level, activated backwashing (the operator had to time and activate/deactivate the low- and high-rate rinses and air scour), and watched the control panel closely so that he could make other adjustments as necessary. This operator also inspected the scale pit (including pumps, level, oil skimming equipment).

It is generally up to the operators to inform their supervisors or the maintenance department of maintenance needs. Again, the maintenance attention required is highly variable. Clarifiers, sludge pumps, and vacuum filters usually require fairly high maintenance attention. Gravity filters and settling lagoons require much less attention. Adequate operator and maintenance attention, however, is obviously important no matter how simple a system is designed. Inadequate attention, operator error, and lack of equipment inspections and preventive maintenance practices will result in eventual system breakdown.

4.4.3 Identification of Effective O&M Practices

The following describes effective O&M practices observed during plant visits and taken from the literature.

Scale Pit Operation--

At four of the HSM systems visited, the scale pits were periodically monitored by hot strip mill operators. These pits did not come under the jurisdiction of the water pollution control operators of the utilities department. Therefore, little information on scale pit O&M practices was available from these plants. It is interesting to note that utilities operators from three plants commented that scale pit operations have sometimes caused solids or oil loading problems on the secondary treatment systems for which they were responsible. It was apparent from discussions that there was a definite division between the process (scale pit) operators and pollution control operators and that communication between the two groups seemed to be minimal and in some cases nonexistant. The utilities supervisor at one plant expressed his concern to the environmental department, which was able to convince the process supervisor to change the scale pit cleanout schedule. The change resulted in less carryover of solids to the filter plant and greatly reduced filter plugging. This change was effective, but it is also interesting to note that it was not uncommon for the environmental department personnel to know little about scale pit operations.

At one of the HSM systems visited, however, the utilities operator also monitored the scale pit operations. This section, therefore, will discuss O&M practices at that plant together with O&M practices described in the literature.

First, since scale pit details were not available from the other plants and since scale pits are common to essentially all plants with hot rolling operations, the following discussion describes the operation of the scale pits at the hot strip mill under discussion.

Wastewater from the roughing mill flume is directed to the No. 1 scale pit where this coarser scale is settled and the clarified water is discharged to a gravity sewer that discharges to an outfall. The scale pit has a retention time of about 42 minutes and a throughput of approximately 15,000 gpm. The enclosed pumping station has four pumps. Two 6000-gpm pumps are used to pump water to the outfall (one operates continuously and the second one kicks on and off depending on wastewater fluctuations). Two 4000-gpm pumps supply the roughing mill with flume flushing water. An ISCO sampler and a Marsh McBirney flow meter are located in the roughing mill scale pit pump line.

Wastewater from the finishing mill flume is discharged to the No. 2 scale pit where the coarser mill scale settles. (A small quantity of water is pumped from the coiler sump to the scale pit.) The pit retention time is about 32 minutes. Wastewater containing the finer solids is pumped from the scale pit to the enclosed filter building housing 12 ultra high rate (UHR) filters. Two feed pumps normally supply wastewater to the filters. A third pump is available on standby. Clean water from the filters is discharged to an effluent sump tank where samples are taken. The water flows by gravity from this tank to an outfall. The effluent sampler (ISCO) takes suction from this sump but is mounted in the filter building. Backwash thickener decant water is returned to the scale pit.

Approximately 15,000 gpm of wastewater are discharged from the finishing mills to the scale pit/filter system during maximum operation of the mills. (Each of the 10 filters then receives about 1500 gpm of water.)

Overflow from the run-out table recirculating pit, which is untreated, is sampled as required at a station using an ISCO sampler. Flow is measured with a Marsh McBirney flow meter. The discharged water flows by gravity to a sewer that ties in with the sewer line carrying discharge water from the high rate filters. The combined stream discharges to the outfall above.

Solids that accumulate in the scale pits are removed periodically by clam shell buckets. Each scale pit is equipped with a Brill rope skimmer made from a polyethylene-type material. The oil is skimmed off and falls into a trough. This oil is drained into a tank car. Most of the oil skimmed from the scale pits is sold to a reclaimer. The remainder is used for coke plant coal bulking and for spraying on roads to control fugitive dust.

Normal losses of oil (~125 gallons per hour) from the mill to the scale pits result from oil leaking from seals and from blown pistons. For example, 200 gallons or more are lost when a piston blows. Occasionally, yellowish hydraulic oil is seen in the scale pits.

The following O&M practices have been used effectively at the plant described above:

- "The most important factor for the proper operation of scale pits is that the material that has settled out is systematically removed."[1] Solids in the scale pits for the plant described are clam-shelled out of the finishing pit once a week and out of the roughing scale pit once a day. This schedule allows the pits to maintain a good working volume and a reasonably constant retention time.

- In addition to regular scale pit cleaning, a management decision was made to clam-shell the finishing scale pit on Sunday (when the hot strip mill was down) to allow the solids adequate time to settle until mill startup the next day. (The cost of paying the clam-shell operator time-and-a-half was worth the problem of heavy solids loading on the UHR filters during the clam-shelling.)

- Frequent inspections of the scale pit by the operator allow him to detect and remove debris (e.g., twigs) on the rope skimmers. Debris on the skimmer can cause oil to be skimmed before it reaches the trough. This is important considering that several hundred gallons of oil would accumulate if a "short-circuited" skimmer went undetected for several hours.

- A good supply of spare rope skimmers is maintained on site. This is more relevant in the colder weather when the skimmers need replacement about every two to three months. A practice that has been fairly successful in reducing skimmer stiffness caused by cold temperature is to attach heat lamps near the skimmer's driving gear mechanism.

- Oil skimmers are usually very effective in removing oil from the scale pits, but slugs of oil resulting from mill maintenance problems can overcome the skimmers and accumulate in the pits. An effective cleanup practice is to have a vacuum truck suck up the accumulated oil. Lack of proper oil removal can cause higher concentrations of oil to be discharged from the scale pits causing secondary equipment problems or an outfall excursion.

- An important practice at the mill described was to have conscientious utility operators who had the responsibility of monitoring the scale pit. With the aid of a level gauge in the filter building control room and by frequent visual observations of the scale pit level, the operator had to manually adjust the flow rates to the filters. Scale pit level can change so drastically that the operators at the plant have to know if water is entering the pit (HSM is operating). If the operator did not monitor the pit level, he could quickly pump the pit to very low levels (pumping out of the pit to the filters at 15,000 gpm), which could cause a reentrainment of solids when the flow to the pit is resumed. On the other hand, pit level would rise when flows to the pit were at a maximum and a filter was on backwash (thickener water discharged back to the pit). Too high a level in the pit could cause water to flood the HSM basement, which would be disastrous to the mill.

Operator Attention/Inspections/Monitoring of Key Parameters--

At one plant whose secondary control system consisted of clarifiers, the following key parameters were monitored and inspections made as they relate to effective O&M practices:

- Maintaining polymer and alum flows to the mixing tank (preceding the clarifiers) where the HSM and cold strip mill wastewaters were combined.
- Taking samples each shift of the mixing tank discharge to measure the pH. It is usually 7.5 to 8. This provides a check against the installed pH meter which must be calibrated frequently.
- Recording torque from gauges at the centerwall of each of the four clarifiers. The normal reading is 0 but can go to 5 to 10 with no resultant problems. Readings greater than 10 can be critical and if they occur the rake drive is shut off to avoid rake damage. The cause of the high torque is investigated and corrected. In the meantime, flow is diverted to the other clarifiers.

Key parameters monitored at a plant with deep-bed gravity filters include:

- Influent and effluent flows are monitored. Magnetic flow meters are calibrated monthly. Other flow meters are calibrated as required.
- Polymer dosage of approximately 12 ppm is maintained on backwash thickener underflow. Use of the polymer has proved to be excellent as reported by the plant. It is added with an in-line mixer and metering pump.
- One operator monitors the filtration plant and performs duties each shift. In addition to periodic inspections of his equipment, he uses a computer to monitor his system. The CRT in the control room is used to observe and regulate such items as filter backwash cycles and flow rates. The CRT and control panel allow automatic scan and alarms if problems arise.
- Filter media is inspected every couple of weeks.

The other plants with settling ponds monitor the following each shift:

- Pond levels and flows
- Oil skimming equipment
- Periodic (every several months at one plant) checks of solids depth in the ponds. One plant determines the level of solids in their basins by taking soundings from a boat. These soundings are

taken at specific points on a grid system along the ponds. Examples of forms based on those used at one of the plants are shown in Figures 4.4-6 through 4.4-8.

Sludge Handling--

It is important that sludge moving and handling equipment be maintained properly and that the sludge consistency be maintained at a good working level. One plant visited maintains a 20 to 30 percent solids content in the sludge of the four clarifiers servicing their HSM. This is done by pumping the sludge from each clarifier about four times each shift. (Sludge samples are also taken each shift to determine solids content.) Sludge from a given clarifier is therefore pumped every fourth shift. The clarifier number is logged so that all operators are sure of the pumping schedule. (Each clarifier has two diaphragm sludge pumps, one being a spare.) Sludge from the clarifiers is pumped to two sludge pits. When one is full, the sludge line is moved to the second pit. The pits are clam-shelled about once a year and the material is taken to a landfill.

Slurry from the plants with deep-bed filters is created in the backwash thickeners. The thickener underflow at one plant is pumped to a centrifuge and at another plant to a vacuum filter. (The plant with the centrifuge formerly used two belt filters for sludge dewatering. Several types of filter cloths were tried but they all quickly plugged with solid fines. They then used a disposable filter type material that came in rolls. This would unwind as the belt moved and was continually discharged with the filter cake. The purchase of a centrifuge proved to be worth the investment. One of the belt filters was replaced with the centrifuge, and the other filter is maintained as a spare during centrifuge outages.) The centrifuge operates with few problems (maintenance is required about every 6 months) and can handle 45 gpm of slurry and produce 2 tons/hour of only 10 to 15 percent moisture sludge.

Sludge thickening has been a problem at the plant with the vacuum filter, which is only about a year old. Fairly often during the year, a consistency of filter cake would form for the first couple of hours of filter use, then the cake would become thin and fall off. The plant was purchasing a different type of filter cloth during the visit so the operation of the filter could not be seen. (No spare was available for use, so backwash thickener slurry had to be temporarily discharged back to the scale pit.

SCHEDULE OF INSPECTIONS

Item	Frequency
1. Oil skimmers and collection system	Daily
2. Polymer system	Daily
3. Basin depth	Monthly (annually for large ponds)
4. Flow rate	Twice weekly
5. Oil level in tanks	Daily
6. Outfall samples	Twice weekly and when necessary
7. Incoming solids content	When necessary
8. Incoming oil and grease content	When necessary

Preventive Maintenance

1. Pump lubrication
2. Trough cleaning and skimmer adjustments
3. Basin dredging
4. Steam heaters

Figure 4.4-6. Example of schedule of inspections for basins/ponds and preventive maintenance items.

Inspected by:
Date:
Time:

SURVEY SHEET - HSM WASTEWATER PUMPS

Scale Pit

Pump sequence: ______
Water level: ______
Pumps operating: 1 ______ 2 ______ 3 ______ 4 ______ 5 ______
Pumps on auto: ______
Pumps on manual: ______
Pumps in the off position: ______
Comments: ______

Runout Table

Pumps operating: 1 ______ 2 ______ 3 ______ 4 ______
Water level: ______
Overflow: Yes ______ No ______
Comments: ______

Contact 80" Mill Electric and/or Mechanical Departments in Case of Difficulties
Contacted: ______ of ______ on ______
Date/time
Concerning: ______

Figure 4.4-7. Example of a survey sheet for inspecting HSM pumps.

SURVEY SHEET - HSM OIL SKIMMERS

Inspected by:

Date:

	Belt skimmers							
	Skimmer operating	Needs trough cleaning	Blades flush	Worn blades	Worn belt	Steam system	Oil level	Comments
HSM ponds								
1.								
2.								
3.								
4.								
HSM scale pits								
1.								
2.								
3.								
4.								

Figure 4.4-8. Example of survey sheet for inspecting HSM oil skimmers.

This is discussed more in "effects of upsets.") Effective O&M practices that could help to alleviate this situation include: use of polymer in thickener underflow stream, and minimizing the amount of oil that goes into and/or comes over from the scale pit. [Maintenance would probably have to be increased to "tighten up" oil leaks from the mill or oil interruption sumps installed at primary leaking areas (if not too numerous) to prevent large amounts of oil from entering the scale pit.] It appeared as though the rope skimmer in the scale pit could not keep up with the incoming oil. Installation of an additional skimmer(s) may be in store or periodic use of vacuum truck service could help if mill leaks cannot be decreased and if the vacuum filter continues to experience sludge dewatering problems. Also, the old vacuum filter needs to be overhauled and maintained so that the plant will have an available spare. At this plant, sludge movement is effectively handled from the backwash thickener to the vacuum filter by two Warren-Rupp diaphragm sludge pumps (one is an on-line spare).

Sludge handling at two of the plants is not done per se because they have settling basins to remove solids. Periodic sludge removal is important, however. One plant has basins lined with two feet of clay and two feet of slag on top of the clay. Great care is taken not to disturb the liner. The plant has been able to clean the basins with a drag line and clam-shell, but this is expensive and has the inherent danger of damaging the liner. The plant has also successfully tried a submersible, hydraulically-driven Flight pump to clean the basins.

Other Effective O&M Practices Observed at Hot Forming Treatment Systems--

The following effective practices were observed or learned from operator/environmental personnel:

- Pipes that are subject to abrasion should be inspected periodically to see if their thicknesses are safe. This can be done with sonic testing.
- Floating booms were strung diagonally across settling basins to direct floating oil and grease to the belt skimmers. Adsorbing booms were stretched across the surface at the basin overflow points to catch any residual oil (the basins discharged to an outfall). These booms are replaced about every 3 to 4 months. Cat walks are provided at the end of the basins so that personnel can gain access to the final settling area and pump off any floating oil if necessary.

- In addition to periodic physical observation of filter media (crushed walnut shells), samples are taken periodically by a contractor who performs an ash test to see how much scale is accumulating. This test is used to determine when the filter media should be changed.

- At one plant, the mill rolling foreman notifies by telephone the utilities operator of shutdown and startup times.

- One plant with a computer monitored system says that in the case of power failures, they have a battery backup to maintain the computer program. They can also rely on the manual control system.

- The setup for getting maintenance on wastewater equipment is very good at one hot strip mill. When repairs are required, the utilities operator calls an assigned maintenance area for assistance. A work order for the repair is issued. The maintenance foreman holds weekly meetings to plan the repairs or modifications if long term. (These meetings can be attended by the utilities operating supervisor.) Daily followup is performed by the assistant foreman to ensure that the maintenance is being performed. The status is relayed to the utilities supervisor. A log is also maintained of equipment failures. Routine preventive maintenance of wastewater-related equipment includes: lubrication; vibration monitoring/testing of major pumps, motors and air blowers; meter calibration; weekly software checking; computer software maintenance; and electrical inspections.

- The use of a small dose (usually 0.01-0.05 mg/liter) of a polyelectrolyte to the influent (of a deep-bed filter) as a filter aid lends flexibility and greater control of the filter process. The addition of the polyelectrolyte to the filter influent has the same effect as decreasing the grain size or pore space. This effect is probably produced by the formation of an adhesive sheath around the individual grains of media. The most effective use of the polyelectrolyte filter aid is normally limited to coarse-to-fine filters (coal-sand or mixed bed), as filters with the fines on top can be sealed off at the surface quite rapidly by this procedure.

Additional descriptions of O&M practices on hot forming wastewater treatment components (e.g., clarifiers/thickeners, filters, oil skimming, chemical addition) are shown in respective subsections in Section 3. Effective communication practices as they relate to a specific process were discussed in Section 4.1 and as they relate to operators and management generally is described in Section 6. This section will be concluded by discussing effective filter backwashing procedures in more detail. Filters (e.g., deep-bed pressure or gravity) are used at a number of plants and will be used more to meet new iron and steel effluent standards.

Filter Backwashing--

As mentioned earlier, proper backwashing of high-rate filters used in the steel industry is very important for optimum operation of the filters. Varied information on several of these filters was obtained during the plant visits. Available information on the types of filters and backwash procedures is summarized for comparison in Table 4.4-1. The information is for normal operation of the filters as practiced by the operators. Deviations to the summarized information occur based on factors such as process upsets and procedures that would affect the quality of water to the filter and cause the operator (if the system is not fully automated) to adjust the backwashing procedure.

Besides the operating practices as illustrated in the table, a few other practices or interesting points as described in the literature are shown below:

- One plant reports that every weekend, when the hot strip mill is down, the sand filters are given an extended backwash to remove the solids accumulation that ordinary backwashes do not remove. Periodically, the filters are also steam cleaned, removing the oil and grease that tend to remain on the filter media, because the excessive oil and grease blinds the filters and causes high influent pressures.[6]
- One reference cited that cationic polymers have been credited with enhancing the quality of the backwash operation and breaking out the oil removed from the filters in the backwash holding tank or scale pits.[2]
- Another reference describing a steel mill converting their ultra-high rate pressure filters to automatic backwashing, reports the following actions to ensure reliable backwashing for their system. They replaced water level probes with mercoid switches, "replaced all limit switches with a style that is sealed to the atmosphere, installed lubrication on all automatic valve bushings exposed to the atmosphere, and ensured the dryness of the air in the instrument air system."[7]

4.4.4 Effect of Upsets/Problems

The effect of process or treatment component upsets and problems can have great adverse effects on the operation of subsequent treatment components and effluent quality if the upset creates pollutant or hydraulic loadings that are greater than the design capability of the treatment component or overall treatment system. Examples are as follows:

TABLE 4.4-1. TYPES OF FILTERS AND BACKWASH PROCEDURES

Application	Type of filter	Filter dimensions	Type/depth of media	Normal time before backwashing	Sequence	Time, (min)	Air/water rates	Pressure in filter: Before wash	Pressure in filter: After wash
To treat 15,000 gpm flow from 80-in. hot strip mill	12 UHR filters (10 in. operation, 1 backwash, 1 spare) Manual operation	12 ft OD 16 ft high	4 ft of anthrafilt and 3 ft of sand (gravel for support)	8 hours	° Drain under air pressure	-		12 ft of water	6 ft of water
					° Low rate backwash	3-4	800 gpm		
					° High rate rinse	6	3,000 gpm		
					° Settle/decant cycles in thickener	40 (4 10-min cycles)			
					° Vacuum filter				
To treat up to 3,000 gpm flow from hot strip mill	5 deep-bed pressure filters automatic or manual	10 ft diameter 37 ft long	3 ft of 4-mm red flint followed by 3 ft of 0.7-mm sand	3½ hours (sand filter backwash of one filter every 42 min	° Prewash	1½	850 gpm		
					° Water/air backwash	13½	850 gpm 1,500 scfm		
					° Clarifier	5 hours			
					° Vacuum filter				
To treat up to 21,000 gpm wastewater from hot rolling mill	2 deep-bed filter vessels; each vessel has 4 cells automatic by timer	15 ft diameter 62 ft long	2 ft of sand and 4-5 ft of anthracite per cell (gravel for support)	2 hours	° Cell drawdown	3		Do not use pressure gauges due to clogging	Do not use pressure gauges due to clogging
					° Air scour	2			
					° Air/water scour	4	5 gpm/ft^2		
					° High rate water backwash	4	30 gpm/ft^2		
To treat contact spray water used to cool hot slab	2 deep-bed type filters automatic at 25 psi or timer (also manual)	-	Crushed walnut shells	6 hours - both cells may be backwashed at same time	° Backwashed with previously filtered water	38	-	4-15 psi	-
To treat blowdown of combined plant process wastewaters including HSM and blooming mills	2 deep-bed downflow gravity sand filter units, 4 cells/unit automatic	488 sq ft per cell	3 ft sand	12 hours minimum per cell	° Draincell				
					° Air backwash		3,500 ft^3/min	-	-
					° Water backwash	5	7,900 gpm (16 gpm/ft^2)		
					° Dewatering				

- Spills or large leaks of oil from hot strip mills typically are washed to the scale pits with the flume flushing water. These slugs of oil in addition to the normal oil discharges can quickly accumulate in the scale pit and "get ahead" of the skimming operations. The skimmers can "catch up" if the mill goes on shutdown for a long enough period(s). Oil that escapes the skimmer(s) and goes into the scale pit discharge will go to the outfall, if it is a direct discharge pit, or to subsequent treatment components.

  If these oil spills or leaks occur frequently, emphasis should be placed on preventing the oil from getting into the scale pit, adding additional skimmers or backup skimming equipment, or contacting a vacuum truck service to remove the oil as needed or on a scheduled basis as two plants have set up.

- The effects of heavy oil loading on secondary treatment plants were reported at two plants visited. An operator at one plant with ultra-high rate pressure filters said that oil buildup in the filter media causes plugging that is difficult to backwash. He said that the oil and solids can occasionally become like a dark thick syrup that at times will take two or more subsequent backwashes to get to the desired filtering pressure. Because of the tight backwashing schedule, additional backwash causes the operators to be extremely busy as they control the backwash sequencing manually from a control panel. (The plant normally backwashes 10 filters every 8 hours. The total filter backwash thickener decant time is about 50 minutes per filter backwash for effective backwashing.) Increased backwashing creates additional wear on the filter media and will lead to ineffective backwashing if the 50-minute time has to be shortened.

  An operator at another plant with clarifiers said that each of their four clarifiers that service the 80-inch hot strip mill and a cold strip mill recently had to be cleaned out because the sludge in combination with excessive oil caused the clarifier rakes to jam and sludge lines to plug. The excessive oil came from the scalping pits (receiving wastewater from the cold strip mill wastewater) that would occasionally accumulate faster than the removal capability of the scalping pits. This excessive oil would overflow into an outlet tank that discharges to the mixing tank and then to the clarifiers. Over a period of time, the oily sludge became too thick and caused the problems. (If the scalping pits become too full of oil now, a vacuum truck is called to pump oil from the outlet tank.) Cleaning each of the clarifiers was expensive. Also, while each clarifier was down, additional hydraulic and solids loading had to be put on the other three.

It is also noted that unnoticed, inoperable oil skimmers can lead to the same results as described above. Frequent inspections and followup action will minimize the effect.

Other examples of upsets/problems that can cause downstream difficulties are:

- Breakdown of mechanical scrapers used at some mills to remove settled scale pit solids. One plant visited reported that their management decided to remove the expensive mechanical scraper system because maintenance requirements were too great and discharge solids loading was excessive (the plant did not have spare settling capacity). Their solution was to go back to the clam-shell method of routinely removing scale.

- Flow surges, which occur frequently from hot strip mills, can resuspend the settled solids in a scale pit if the pit level is too low. Maintaining an optimum level (i.e., not too low or too high so that a chance of overflow could occur) will help minimize turbulent action. Allowing maximum retention time in a pit or having several pits will also counteract flow surges.

- The clam-shell operator should try to remove scale in a fairly even manner so that solids will not accumulate in certain missed areas. Avoidance of this could cause short circuiting of the available pit retention space.

- Two plants reported that a significant amount of filter media was lost during backwashing. The plant had to take those filter cells out of service and replace the media. At one plant, wire strainers were installed above the media to prevent loss. Operators at the other plant said they decreased the time of air scour and rinse flow by a couple of minutes and have not had any more problems.

- Just prior to visiting one plant, their relatively new vacuum filter was taken out of service. The old vacuum filter had not yet been refurbished to be available as a spare. Both the first and second shift operators said that when the vacuum filter is inoperable, the increased suspended solids to the scale pit water (from thickener decants) and subsequently to the UHR filters cause the backwash frequency to have to be increased significantly. (One operator said that in this mode of operation, the total number of backwashes per 8 hours increases from 10 to 12, to 15 to 17.) Although influent from the filters was still very clear during the visit, the most notable effect was on the operators who had to be continuously busy and alert. (This is the same system described earlier in which the operator operates the control panel manually.) The situation of having a closed-loop solids system would cause solids concentrations buildup and backwash frequency increases to eventually hinder UHR filter operation until solids could be removed.

4.4.5 Relationship Between O&M Practices, Upsets, and Effluent Quality

Many of the types of upsets described in the previous subsection can cause a degradation of effluent quality and could result in permit excursions.

There is a more distinct relationship for systems that discharge directly to an outfall rather than systems that discharge to a terminal treatment plant where there is further pollutant removal. There is a more vague relationship too if the discharge water from a system is recirculated for process reuse, with only a blowdown stream. Upsets and problems that degrade water quality in a tight recycle system can adversely affect process-related equipment (e.g., solids can plug spray nozzles on product cooling lines) and product quality.

Most of the upsets described could have been minimized or eliminated with effective O&M practices. For example, frequent cleanout of scale pits on a scheduled basis (during mill shutdown if possible) will help maintain design retention times; prevention or redirection of oil leaks and spills will minimize loading to scale pits; frequent inspection and correction of oil skimming equipment will maximize its removal efficiency; contracting for vacuum truck service to come-on-call or on a scheduled basis will prevent overaccumulation of oil; having spare equipment (e.g., pumps, filters, vacuum filters) and keeping them operable will obviously allow an intermediate solution if equipment breakdowns occur (rotation of the operating and spare equipment is practiced at a number of plants); periodic sampling/monitoring of wastewater streams at different points will show deviations from "normal" conditions that cannot be detected visually so that troubleshooting efforts can be initiated; and there should be adequate communication between process and utility operators to inform the latter at least of major leaks or of mill shutdowns/startups.

Some specific examples of permit excursions, some related to operation and maintenance practices, are summarized in Table 4.4-2.

TABLE 4.4-2. EXAMPLES OF HOT FORMING WASTEWATER PERMIT EXCURSIONS

Cause of problem	Parameter/pollutant exceeded	Date	Actual concentration	Allowable concentration
Plume caused by scale pit fines	TSS	4/23/82		
Scale pit being cleaned	TSS	6/19/80		
Malfunctioning oil skimmer	O&G, kg/day	4/14/82	6,136	5,409
Scale pit cleanout	TSS, kg/day	2/81	2,080	1,022
Buildup of scale in scale pit	TSS, kg/day	9/80	559	296
Cleaning of HSM floor increased oil to clarifier	O&G, kg/day	2/80	248	210
Loss of cationic polymer feed to plate mill service water system filter backwash line	TSS, lb/day O&G, lb/day	9/4/79	11,770 2,344	8,800 1,350
Irregular manual operation of gravity filters in attempt to drain a pre-filter settling basin-HSM/blooming mill	TSS			
Broken steam line connection to a submerged steam heater in an oil skimmer tank	O&G	12/10/80		
Position of weir in scale pit did not allow maximum retention of scale particles	TSS, mg/liter	2/12/81	55	50
Maintenance problem on HSM horizontal scale breaker caused oil overload to roughing mill scale pit	O&G, mg/liter	2/12/81	12	
A blockage of the furnace discharge flume flooded extractor pit basement which hydraulically overloaded the roughing mill scale pit	O&G, mg/liter	11/1/81	14	

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4.5 ACID PICKLING

The steel industry is a major consumer of acids in the United States. About 50 percent of the products in an integrated mill may be acid pickled. Acid consumption varies widely--from a low of about 10 lb/ton to a high of about 50 lb/ton of steel. The volume of water used for rinsing is 50 to 100 gallons per ton of steel pickled.[1] Wastewater is generated from three sources in the pickling operation: rinse water, fume scrubber water, and spent acid.[2] Rinse water, which is often the largest of the three sources, contains suspended solids and dissolved metals. Fume scrubber blowdown water from sulfuric and hydrochloric acid pickling operations is completely reusable as makeup water in cascade rinse systems. Spent pickle liquor is highly contaminated, but it is also the lowest in volume of the three wastewater sources. Normally this flow is either regenerated or disposed of by hauling to a contract disposer or by deep-well injection.

The two types of treatment technologies covered in this section are lime precipitation/neutralization and acid regeneration.

4.5.1 Arrangement of Treatment Components

Lime Precipitation--

Figure 4.5-1 shows the components of a chemical treatment system for treating waste pickle liquor together with rolling mill wastewater. These two streams are combined in an oil decant tank that also serves as an equalization vessel. The pH at this point is generally between 2 and 4, and enough acid is present to break oil emulsions so the oil will float to the top of the tank for removal. The underflow from the decant tank goes to an oil separator, which removes more of the waste oils. Oil is removed from the separator with a skimmer and then combined with the decanted oil. From the separator, the liquid flows to a rapid (or flash) mix tank. From the rapid mix tank, the liquid flows into an aeration tank, where an agitator-type aerator violently mixes the liquid to bring it into contact with the air above the liquid level. Limestone and hydrated lime are added at this point to bring the pH up to 8 or 9. The purpose of the aeration tank is to oxidize the ferrous (++) iron to ferric (+++) iron, which is less soluble. The high pH causes the formation of ferric hydroxide, an insoluble floc that will capture and settle out any residual emulsified oil droplets as well as some heavy metals in the clarifier.

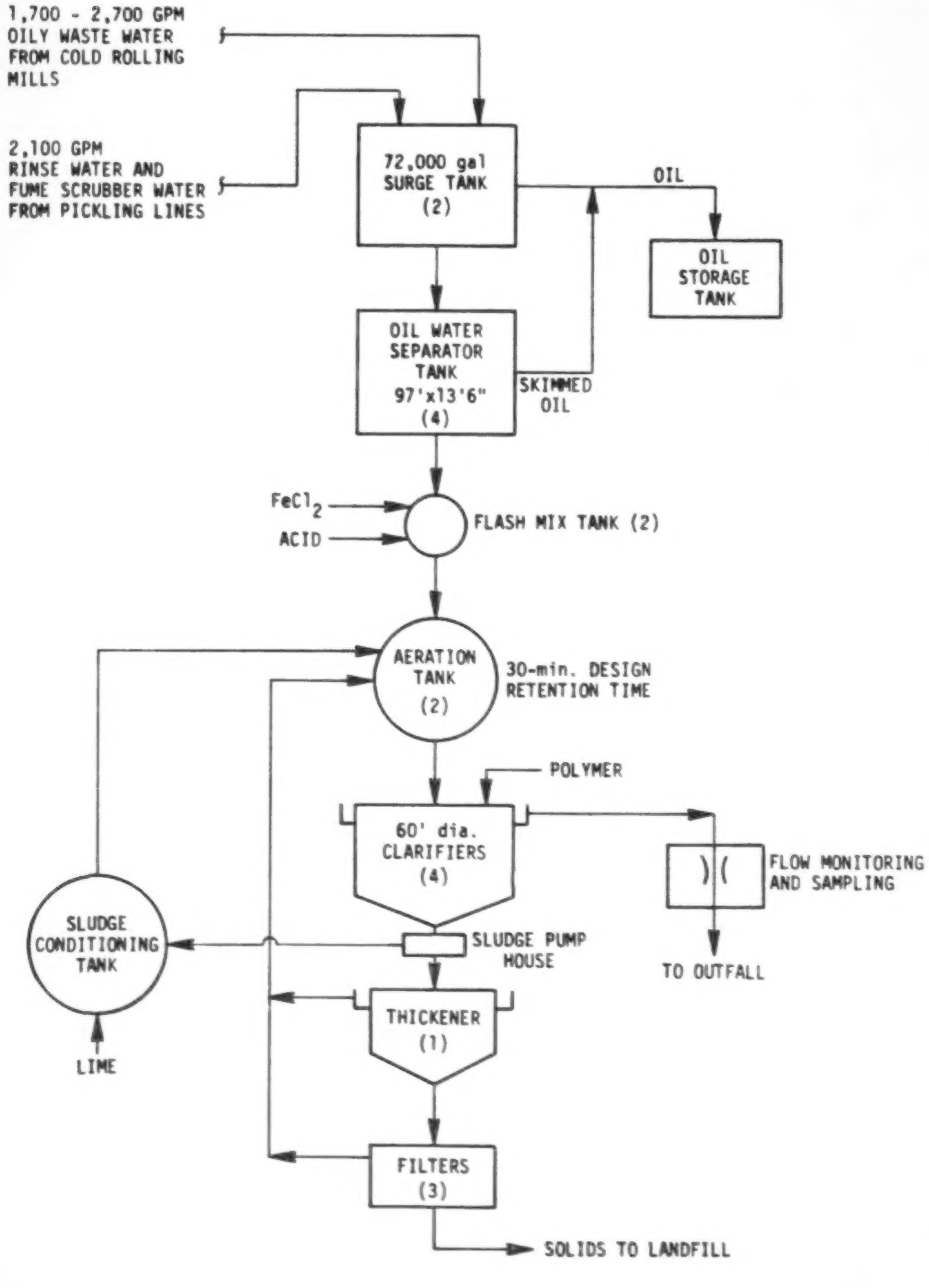
1,700 - 2,700 GPM
OILY WASTE WATER
FROM COLD ROLLING
MILLS
2,100 GPM
RINSE WATER AND
FUME SCRUBBER WATER
FROM PICKLING LINES
72,000 gal
SURGE TANK
(2)
OIL
OIL
STORAGE
TANK
OIL WATER
SEPARATOR
TANK
97'x13'6"
(4)
SKIMMED
OIL
FeCl2
ACID
FLASH MIX TANK (2)
AERATION
TANK
(2)
30-min. DESIGN
RETENTION TIME
POLYMER
60' dia.
CLARIFIERS
(4)
FLOW MONITORING
AND SAMPLING
TO OUTFALL
SLUDGE
CONDITIONING
TANK
SLUDGE PUMP
HOUSE
THICKENER
(1)
LIME
FILTERS
(3)
SOLIDS TO LANDFILL

Figure 4.5-1. Acid pickling rinse water/cold rolling treatment system.

Water from the aeration tank flows to clarifiers, where the ferric hydroxide settles out and carries with it contaminants in the water. The clarifier overflow goes to an outfall. The sludge from the clarifier is pumped to a thickener, where it is stored and further conditioned. Polymers can be added to the clarifier and the thickener to improve the settling rates and sludge properties.

Some of the sludge from the clarifier is pumped to a sludge-conditioning tank, where lime is mixed with the sludge before the mixture is recycled to the aeration tank. The recirculated sludge helps settle out the newly formed floc by providing a nucleus for floc sludge formation.

The underflow from the thickener is pumped to a filter for dewatering. The thickener overflow can either go directly to the outfall or be recycled back to the clarifier. The filter cake is usually picked up by a contract disposer, and the filtrate can be recycled back to the clarifier.

Hydrochloric Acid Regeneration--

The only commercially proven technology for regenerating spent hydrochloric acid is through thermal decomposition.[2] The Lurgi fluidized-bed reactor system is discussed in this section. A diagram of this system is shown in Figure 4.5-2.

In the pickling reaction, hydrochloric acid removes iron oxide from steel to produce ferrous chloride and water:

$$FeO + 2HCl \rightarrow FeCl_2 + H_2O$$

The Lurgi process reverses this reaction and converts the ferrous chloride to ferric oxide and hydrochloric acid:

$$4FeCl_2 + O_2 + 4H_2O \rightarrow 2Fe_2O_3 + 8HCl$$

Hydrogen chloride is given off in the gaseous state and is absorbed in water to form hydrochloric acid.

This reaction occurs in the kind of reactor shown in Figure 4.5-2. Natural gas burners provide heat to the reactor. Waste pickle liquor at a strength of about 40 grams per liter of free HCl is fed into the reactor via the pre-evaporator. Air is fed into the reactor to provide the oxygen necessary for combustion and for the reaction.

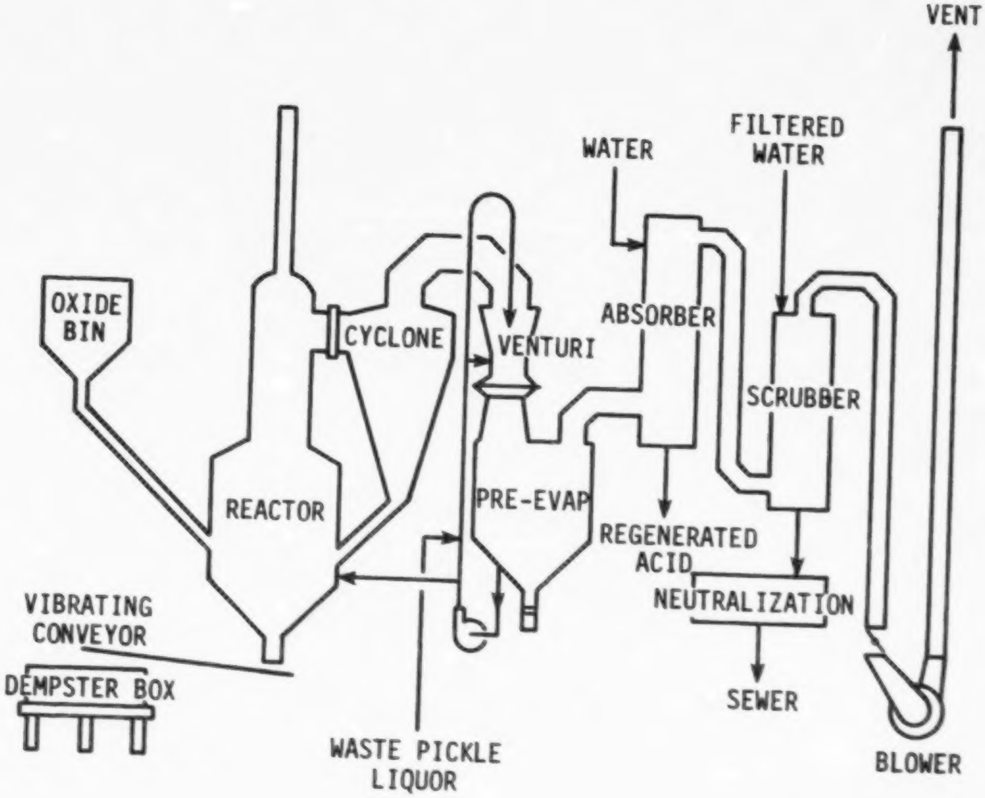
VENT
FILTERED WATER
WATER
OXIDE BIN
CYCLONE
VENTURI
ABSORBER
SCRUBBER
REACTOR
PRE-EVAP
REGENERATED ACID
NEUTRALIZATION
VIBRATING CONVEYOR
DEMPSTER BOX
SEWER
WASTE PICKLE LIQUOR
BLOWER

Figure 4.5-2. Lurgi hydrochloric acid regeneration process.

Iron oxide is removed from the bottom of the reactor through discharge chutes. The combustion and reaction gases entrain small iron oxide particles (typically less than 200 micrometers in diameter), and these particles are removed in the cyclone and returned to the fluidized bed. The small particles serve as seed on which the oxide can grow and produce particles large enough to drop out of the reactor. Iron oxide is added to the reactor from an external source during startup.

The hot gases from the cyclone go through a venturi, where they are cooled with waste pickle liquor from about 1500°F to about 200°F. From the venturi, the solution flows to the pre-evaporator. The liquor from the pre-evaporator is recycled back to the venturi and also pumped into the reactor.

The gas stream containing the combustion and reaction products goes from the pre-evaporator to an absorber, which is a packed column. Liquid is recycled through the absorber to build up the hydrochloric acid content to the desired level of about 150 grams per liter.

The gas coming off the top of the absorber contains trace amounts of hydrochloric acid and fine iron oxide particles. These contaminants are scrubbed out in another packed column. Filtered recycle water from another plant operation is used as the scrubbing medium. The effluent from this scrubber typically has a pH of 2 to 3. This effluent is neutralized with caustic soda and discharged. The gases from the scrubber go to a fan that provides the motive force for flow through the entire system. These gases are then discharged to the atmosphere.

4.5.2 Identification of Major Areas of O&M Concern

Chemical Treatment Plant--

Problems or concerns are discussed individually in this section; the solutions are presented in the same order in Section 4.5.

Sludge accumulation--Because the oil decant tank and the oil separator are not agitated, sludge will settle out and accumulate on the bottom of these vessels. Eventually, this accumulation will reduce the residence time in these vessels to the point that they lose their effectiveness.

pH monitors--The pH in the oil separator should be in the range of 2 to 4 to break oil emulsions effectively. The pH in the aeration tank should be between 8 and 9 to form the ferric hydroxide floc. A pH above 9 indicates that too much lime is being added and thus wasted; whereas a pH below 8 means that more lime is needed and insufficient hydroxide floc is being formed.

Lime addition--The lime addition to the aeration tank is a mixture of limestone and hydrated lime. Limestone produces a better filter cake and clearer effluent than does hydrated lime. Hydrated lime is necessary, however, to attain the necessary pH (8 to 9) to improve the oxidation rate. If limestone alone is used, the pH could be raised to only between 6.5 and 7.

Sludge buildup in aeration tank--Solids accumulate in the aeration tank during normal operation. These solids typically build up on the walls and bottom of the tank. Eventually, they will reduce the residence time in the tank to the point where the amount of aeration occurring is inadequate.

Acid Regeneration System--

Exhaust fan--One plant reported problems with emissions of very fine dust from the exhaust stack on their regeneration system. Liquid droplets and oxide fines are normally carried into the fan and removed by a drain line on the fan. If this drain line becomes plugged, the liquid and entrained particles accumulate and eventually can spray out of the stack.

Reactor cyclone--The recycle line from the bottom of the cyclone to the reactor has a check valve to prevent gases from going up into the bottom of the cyclone. This check valve will sometimes hang open. When this happens, dust carryover from the cyclone to the evaporator becomes excessive and increases the solids content of the liquor in the evaporator to as high as 3 percent by weight. When this occurs, the abrasion on the pre-evaporator centrifugal pump can cause the pump to fail. On the other hand, when these valves do not open properly, dust can build up in the cyclone. A sudden release of accumulated dust from the cyclone into the reactor can defluidize the reactor.

Waste pickle liquor feed point--The waste pickle liquor solution at one plant was initially fed by lance into the side of the reactor. However, oxides would build up and plug the lance.

System pressure drop--At one plant the pressure drop in the system was about 15 in. across the venturi, 20 in. across the absorber, and 5 to 15 in. in the rest of the system. The plant tried to maintain this system at about 2 in. of vacuum. If the pressure should go positive, acid fumes could leak out into the plant.

Preventive maintenance--The acid recovery system handles hot dilute liquid hydrochloric acid (HCl) and HCl vapors. This is a very severe service, and its proper operation requires constant attention to maintenance.

Fines formation--For the system to operate properly, the iron oxide must form the proper particle size. Normally the oxide is gray, but sometimes it will change to a fine red dust that the cyclone will not remove. Once this happens, the system has to be shut down and cleaned out before it is restarted. About five hours are required to bring a unit back up.

4.5.3 Identification of Effective O&M Practices

Chemical Treatment System--

Sludge accumulation--The decant oil tank and oil separator should be checked periodically for sludge accumulation. The plant should have a formalized system for periodically monitoring this. When the sludge builds up to the point that the residence time in these vessels is unacceptable, the vessels should be taken out of service and cleaned.

pH monitors--The readout of pH monitors in the system should be checked frequently with a portable pH meter. The portable meter is calibrated by using standard buffer solutions. If the pH monitor's reading disagrees with the reading of the calibrated portable meter, the monitor should be adjusted.

Operators at one plant checked the pH on an hourly basis and plotted each reading on a daily chart. The chart has two heavy lines at pH 8.2 and pH 9.5 to serve as their control range. This is an effective way to illustrate the pH control and variation in the aerators.

Lime addition--Proper ratio of hydrated lime to limestone should be maintained. One plant used a ratio of 30 percent hydrated lime to 70 percent limestone. Shipments of lime should be checked to ensure that they meet plant quality standards. One plant found that obtaining lime from a single supplier resulted in more consistent quality.

The lime and water are mixed to form a slurry before being added to the aeration tank. One plant had an automatic system that continuously metered and mixed the lime and water; however, they found that their lime feeder worked better if it operated at a higher rate, so the system was converted to a batch system. This conversion provided a more consistent lime slurry.

Sludge buildup in the aeration tank--The operator should periodically check for sludge buildup in the aeration tank by poking a stick or piece of pipe into the tank to feel where the buildup is. When the buildup becomes excessive, the tank should be shut down and cleaned out.

Acid Regeneration System--

Exhaust fan--If liquid accumulates in the exhaust fan in the acid regeneration unit, it will eventually blow out the top of the fan. This creates a mist containing fine red oxide dust. In one installation, the fan was at grade and the drain from the bottom of the fan would periodically plug and create this condition. Ideally, the fan should be located above grade so that a barometric seal can be installed for the drain. This would also prevent the fan from drawing water back up the drain and blowing it out the stack.

Reactor cyclone--The operator should be aware that the check valve in the line from the bottom of the cyclone to the reactor can plug in either the open or closed position. The disruptive effect this has on the process must be understood so the operator can free the check valve when these upset conditions begin to occur. If the valve hangs shut, oxide particles can build up and suddenly be dumped into the reactor as the valve breaks open, which will defluidize the reactor. On the other hand, if the valve hangs open, oxide can be carried over into the pre-evaporator and the fine particles will abrade the pre-evaporator pump. One plant was using a graphite pre-evaporator pump that would be damaged by these particles. They were planning to try a ceramic pump in this service. The ceramic pump should be resistant to the acid and at the same time resistant to abrasion. This type of pump is more expensive than a graphite pump, and it has not yet been determined if it is economically attractive.

Waste pickle liquor feed point--One plant fed the waste pickle liquor into the side of the reactor through a lance. Oxides would build up and plug this lance. To solve the problem, they changed the feed point and introduced the lance into the bottom of the reactor in a section that was more highly fluidized. The increased turbulence in the new location apparently kept the lance clean.

System pressure drop--The operator must monitor the pressure to ensure that a vacuum is always maintained in the system. This is to prevent acid fumes from leaking out of the system into the plant as the pressure in the regeneration system becomes positive.

Preventive maintenance--Because the service in an acid regeneration plant is severe, a preventive maintenance schedule is imperative. One plant replaced 15 percent of the gas burners in the reactor every 9 months and replaced exhaust fan motor bearings and pump seals on a regular basis. All pump and compressor bearings were also checked periodically. Maintenance labor costs at this plant were higher than operating labor costs.

Fines formation--For reasons not thoroughly understood, sometimes the normally gray iron oxide (Fe_2O_3) will no longer be formed and a fine red dust will be made instead. This fine dust will cause a shutdown. Adding magnetite (Fe_3O_4) seems to inhibit this reaction. One plant added about 100 lb of magnetite twice a day to help keep fines from forming. The magnetite was added to the reactor through the cyclone.

4.5.4 Effect of Upsets/Problems

Chemical Treatment System--

Sludge accumulation--If sludge builds up in the oil separator and reduces residence time too much, oil that would otherwise be skimmed off will be carried over into the rest of the system. Because of this additional oil and grease, more waste pickle liquor must be added to the rapid mix tank. This in turn requires the addition of more lime. With the available equipent it may not be possible to provide enough aeration to oxidize all the irn, and the unoxidized iron can be carried over the clarifier weir into the otfall. Also, using more lime creates additional cost, not only for the lie but for additional sludge disposal when the lime is removed at the filter pH monitors--If the pH monitors are inaccurate and the pH in the aeration tank is too low, ferric hydroxide will not be formed and excessive iron will be carried over at the clarifier. Too high a pH causes lime to be wasted and increases the load on the filters.

Iron and oil and grease content in the rapid mix tank--If the iron content in the rapid mix tank is too high, aeration capacity will be insufficient to oxidize all of the iron, and the unoxidized iron will overflow the clarifier to the outfall. If the iron content is too low, insufficient iron hydroxide floc will be formed. This floc is necessary to capture and settle out oil and grease in the clarifier. If floc formation is insufficient, the clarifier overflow will send higher levels of oil and grease to the outfall.

Lime addition--If improper lime addition causes poor pH control, the results are the same as those discussed under pH control. If the lime itself has too high a ratio of limestone to hydrated lime, excess lime would have to be used to obtain the proper pH. This would result in a more expensive operation because of the use of additional lime and because of the resulting additional filter cake that would have to be disposed of. If the ratio of hydrated lime to limestone is too high, the filtration operation will be more difficult. The limestone acts as a filter aid.

Sludge buildup in the aeration tank--Sludge buildup in the aeration tank decreases the effective volume of the tank and the amount of aeration that occurs. If the aeration is insufficient, not all of the iron will be oxidized. The unoxidized iron is more soluble and will tend to exit with the clarifier overflow and cause higher iron levels in the plant effluent.

Acid Regeneration System--

As discussed in Section 4.1.3, most upsets that occur in the acid regeneration system will force a shutdown. Because acid regeneration is part of a closed-loop system within the plant, these upsets normally do not affect water quality. (They can cause the red dust air pollution problem described earlier.)

4.5.5 Relationship Between O&M Practices, Upsets, and Effluent Quality

The effects of upsets on the quality of effluent from the chemical treatment system were discussed in Section 4.5.4. Since high volumes of water continuously flow into the system and then out of the system to an outfall, most upsets will result in a carryover of some amount of iron, oil, or suspended solids to the outfall.

The acid regeneration system, on the other hand, is a closed-loop system within the plant. Upsets in this system have very little effect on effluent quality (a potential water pollution problem would be from an acid spill or tank leak). The only flows from this system into the environment are directly from the exhaust stack or from fugitive losses in the system. If the system pressure becomes positive, hydrochloric acid will be leaked into the plant. If water accumulates in the exhaust fan, it will be blown out the exhaust stack along with fine red oxide dust. These malfunctions were discussed in earlier sections.

Specific examples of permit excursions, some of which are related to operation and maintenance practices, are summarized in Table 4.5-1.

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TABLE 4.5-1. EXAMPLES OF ACID PICKLING WASTEWATER PERMIT EXCURSIONS

Cause of problem	Parameter/ pollutant exceeded	Date	Actual concentration	Allowable concentration
Pump breakdown for waste acid pickle liquor causing overflow at storage tank. System controlled pH but not iron	Fe, lb/day	5/18/80	247	138
Two significant violations due to cleaning out of No. 6 pickler department on sampling day	O&G, kg/day	3/81	10.3	9.1
Broken level indicator on waste acid tank on pickle line caused an overflow	Fe, lb/day	10/30/81	833	138
Pickle line overflow (pipe plugged and waste pickle acid was diverted to treatment plant)	Fe, lb/day	1/26/77	144	138
Operator error and pickling rinse water neutralization facilities	pH	2/10/82	1.4	6.0 (min)
Overloaded treatment system caused by spent pickle liquor spill	pH	8/80	3.7	6.0 (min)
Tank rupture on pickle line caused acid spill to lagoon. Effect magnified by low water level, high winds, and concurrent dredging operations in basin	Fe, mg/liter	1/22/80 1/23/80	10.3 10.9	2.0 2.0
Extremely variable influent pH to rinse water neutralization treatment plant occurred during this sustained period of low production	pH	3/82		
Small amount of water attributed to small transfer pump being repaired at No. 3 pickler		2/82		

SECTION 5

MONITORING OF CRITICAL PARAMETERS/INSTRUMENTATION

This section describes several types of monitoring devices that are commonly used in wastewater treatment systems in the iron and steel industry. It also describes problems with the devices and effective O&M practices. The specific devices for flow, pH, level control, and oxidation-reduction potential (ORP) are described in more detail than other devices because most of the plants visited have experienced problems with them. A general section on instrumentation briefly describes other important monitoring devices also frequently used in the industry, but with fewer reported problems.

5.1 FLOW-METERING DEVICES

Flow control is required in most steelmaking processes, primarily to maintain hydraulic balance. For most contact water processes, flow rates are generally not critical. Flow metering is of the most concern in wastewater treatment systems where it is necessary to calculate waste loadings, to control makeup and blowdown, and to preserve hydraulic balance. Because most steel plants were not built to accommodate good flow metering, they usually must be retrofitted under difficult circumstances. For example, outfalls are often crude ditches with pipes that are either underground or otherwise inaccessible and flow rates are often high, sometimes in excess of 50,000 gpm. Flow metering also is complicated by the many streams involved in a given system.

5.1.1 Types of Flow-Metering Devices

Flow-metering devices vary from plant to plant and also according to the controls for each process. The following are some of the flow-metering devices that are used:

Weirs--

The weir is commonly used to measure fluid flows because it is easy to install and inexpensive. A weir (Figure 5.1-1) is basically a dam at right angles to the flow in a duct, flume, or sluice, which has a controlled opening centered at the top. Weirs can be "v-notch," rectangular, Cipolletti, or a slight variation of these basic designs. If the height of the water above the base or crest of the notch is known, the flow can be determined.

Parshall Flume--

The Parshall flume (Figure 5.1-2) is a venturi-type unit that has a converging upstream section, a downward-sloping throat, and an upward-sloping diverging downstream section. The Parshall flume, which is placed as a section of the duct, flume, or sluice is dependent on a free-flowing condition. It is necessary to know the height of the flow at the entrance to the converging upstream section to determine the flow. The height of the flow should be measured back from the crest of the flume at a distance equal to two-thirds of the length of the converging section. The crest is located at the junction of the throat and converging section. It is recommended that

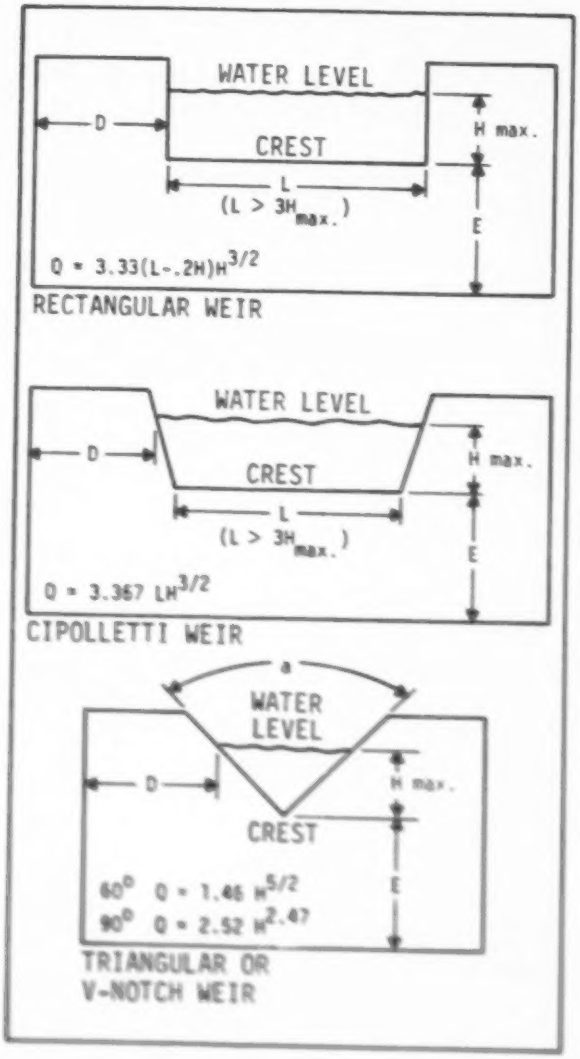
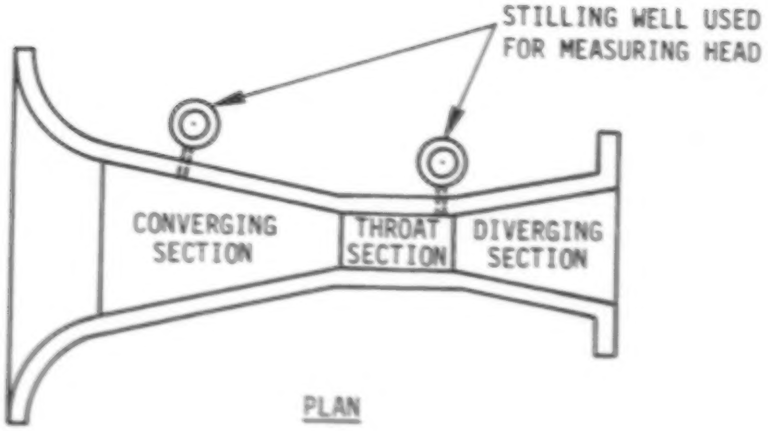
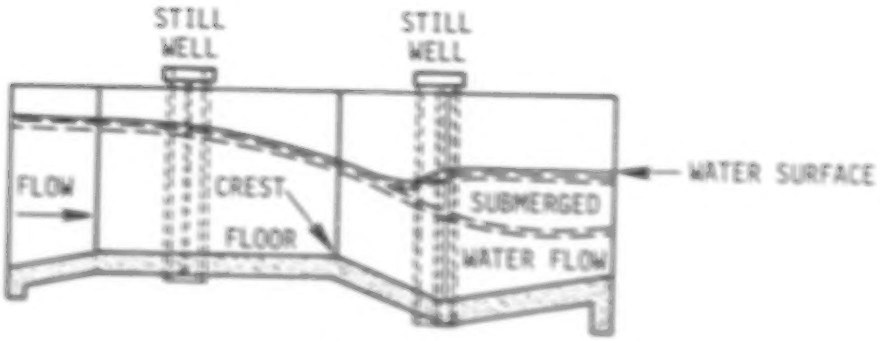

WATER LEVEL
D
CREST
H max.
L
$(L > 3H_{max.})$
E
$Q = 3.33(L-.2H)H^{3/2}$
RECTANGULAR WEIR
WATER LEVEL
D
CREST
H max.
L
$(L > 3H_{max.})$
E
$Q = 3.367\ LH^{3/2}$
CIPOLLETTI WEIR
a
WATER LEVEL
D
H max.
CREST
E
60° $Q = 1.46\ H^{5/2}$
90° $Q = 2.52\ H^{2.47}$
TRIANGULAR OR
V-NOTCH WEIR

Figure 5.1-1. Three common types of weirs.[1]

D $\geq$2.5 x maximum head (H max.)
E $\geq$2 x maximum head (H max.)
Q = actual discharge, cfs
L = crest length, ft
H = measured head, ft


STILLING WELL USED
FOR MEASURING HEAD
CONVERGING SECTION
THROAT SECTION
DIVERGING SECTION

PLAN


STILL WELL
STILL WELL
WATER SURFACE
FLOW
CREST
FLOOR
SUBMERGED
WATER FLOW

SECTION

Figure 5.1-2. Plan and section view of a Parshall flume.[1]

the head of the water surface in the converging section be measured in a stilling well instead of the flume itself, as the stilling well dampens sudden changes in flow. Capacity curves for Parshall flumes are shown in Figure 5.1-3. Sometimes eddy effects or submerged flow conditions result from high water elevations downstream. If the flow is submerged, the velocity of the flow decreases. Since calibration of the flume is based on free flow conditions, the degree of submergence must be determined. The condition of submerged flow is evidenced by a ripple or wave formed just downstream from the end of the throat. It is therefore recommended that a still well be installed in the downstream end of the throat section to determine the degree of submergence.

Open-Flow Nozzle--

Open-flow nozzle (Figure 5.1-4) is a device that can be used for partially filled pipes and low flows. Two common types are the Kennison nozzle and the parabolic flume. These nozzles are attached to the end of a pipe or flume. Each nozzle is rated according to the relationship between the water level in the nozzle and the flow. Table 5.1-1 gives capacities of the Kennison nozzle. These devices can be used to register flow continuously by placing a float in the nozzle that is connected to a recorder.

TABLE 5.1-1. CAPACITIES OF THE KENNISON NOZZLE[a]

Inlet diameter, in.	Gal/min	Million gal/day
6	200	0.29
8	310	0.45
10	590	0.85
12	870	1.25
16	1,900	2.7
20	3,100	4.5
24	5,200	7.5
30	8,000	11.5
36	13,500	19.4

Other Basic Devices--

The thin plate orifice, flow nozzle, and venturi tube (or Dall tube) permit determination of the flow rate by measuring the pressure differential across the flow restriction in the pipeline.

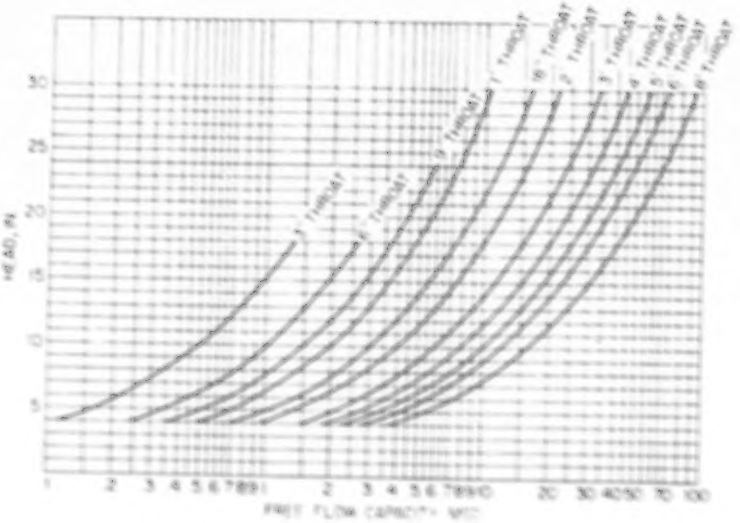


Figure 5.1-3. Capacity curves for Parshall flumes.

Courtesy of Considine, D. M. Process Instruments and Controls Handbook. McGraw-Hill Book Company, New York. 1974.

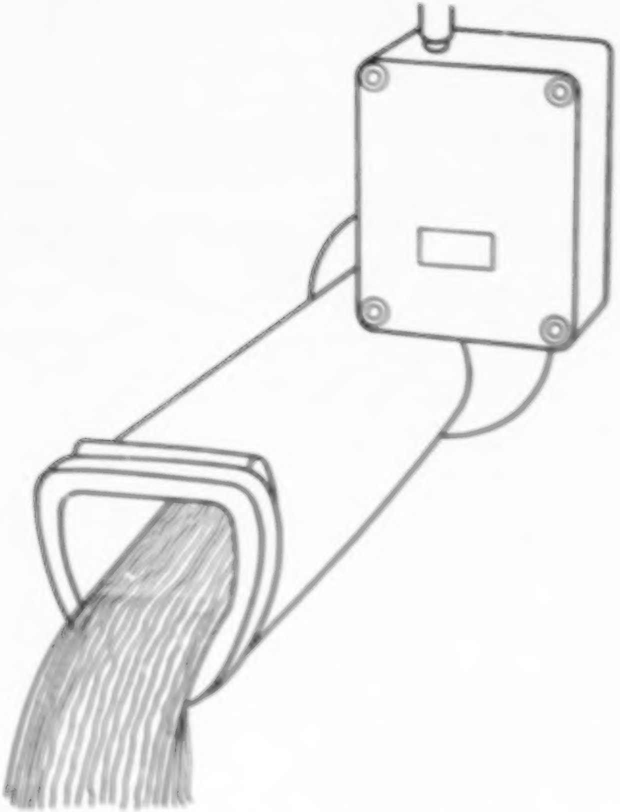


Figure 5.1-4a. Open-flow nozzle with instream transmitter.1

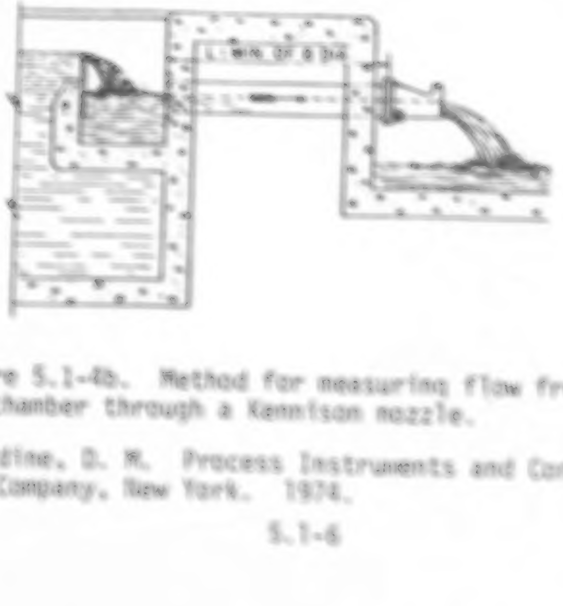


Figure 5.1-4b. Method for measuring flow from a chamber through a Kennison nozzle.

ourtesy of Considine, D. M. Process Instruments and Controls Handbook. McGraw-Hill Book Company, New York. 1974.

- The thin plate square or sharp-edged orifice (Figure 5.1-5) can be inserted into a pipe at right angles to the flow and between two adjacent pipe flanges. A flange spreader is used to ease removal for cleaning and inspection.
- A bell-shaped flow nozzle with a nozzle throat (Figure 5.1-6) can be inserted into the line in the same manner as the thin plate orifice.
- The venturi tube (or Dall tube) has a converging approach section followed by the throat and discharges through a diverging section.

Magnetic Flow Meters--

Magnetic flow meters (Figure 5.1-7) can be inserted in a line to determine the flow rate if the fluid flowing is electrically conductive. Magnetic flow meters can be used successfully in places where other types of meters would become plugged with solids. The magnetic flow meter also does not result in head loss; the pressure drop is no greater than for flow through an equivalent length of pipe.

Variable Flow Meters--

- Rotameters (Figure 5.1-8) have a float in the stream to indicate the flow by direct viewing through a glass or a linked magnetic recorder. The entire stream must flow through the annular space between the float and the tube wall. Therefore, rotameters are normally used for measuring small flow rates of clear, clean fluids such as process water. Maintaining the accuracy in a rotameter requires that both the tube and float be kept clean.
- Orifice and tapered plug meters have a magnetic float within a tapered float assembly adapted to an orifice plate in the line.
- Piston-type meters have a sleeve or cylinder set at right angles to the flow. An orifice in the sleeve or cylinder is mated to a metering plug or fitted piston. The flow, which passes through the orifice and displaces the piston or plug, can be measured through a glass tube arrangement above the meter.

Meters Used for Special Installations--

- Turbine meters with a multiblade rotor in the stream in the pipe
- Vortex velocity meters with a multiblade rotor; the rotor receives a portion of the main flow
- Rotating meters
- Lobed-impeller, sliding-vane, and retracting-vane rotary-flow meters

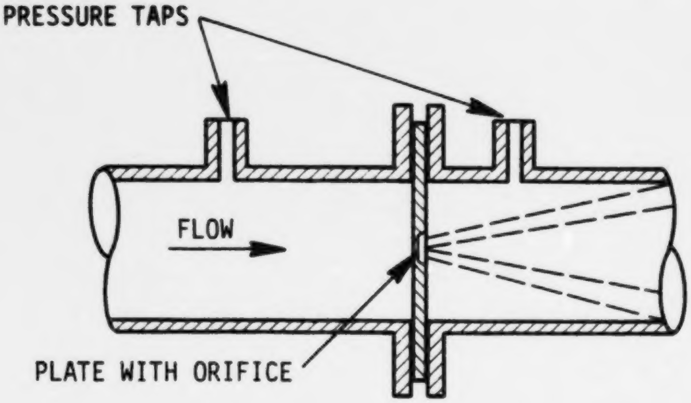

PRESSURE TAPS
FLOW
PLATE WITH ORIFICE

Figure 5.1-5. Orifice in pipe.

Courtesy of Chemical Engineers' Handbook. 5th Ed., A. H. Perry and C. H. Chilton, eds. McGraw-Hill Book Company, New York. 1973.

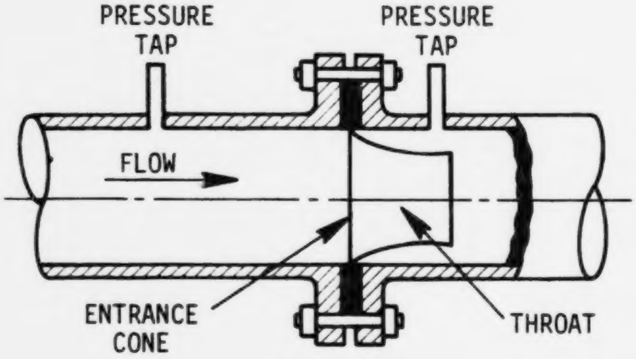

PRESSURE TAP
PRESSURE TAP
FLOW
ENTRANCE CONE
THROAT

Figure 5.1-6. Flow nozzle in pipe.[1]

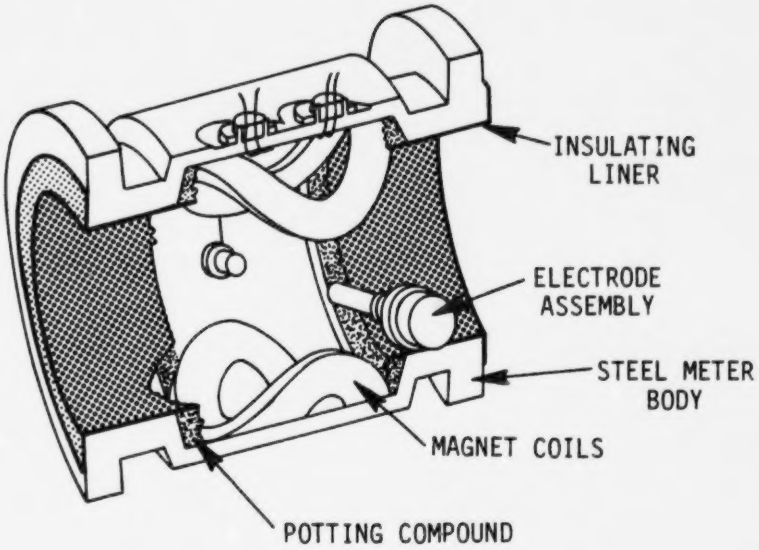

INSULATING LINER
ELECTRODE ASSEMBLY
STEEL METER BODY
MAGNET COILS
POTTING COMPOUND

Figure 5.1-7. Magnetic flow meter.[1]

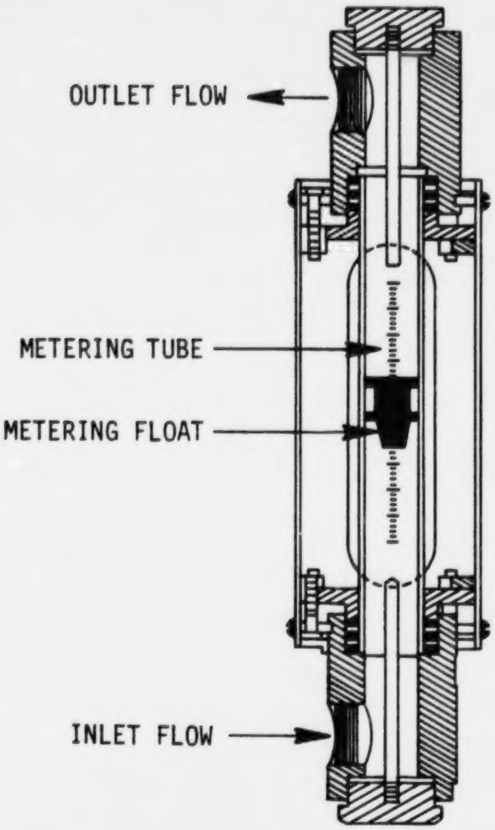

OUTLET FLOW
METERING TUBE
METERING FLOAT
INLET FLOW

Figure 5.1-8. Rotameter.

Courtesy of Chemical Engineers' Handbook. 5th Ed., A. H. Perry and C. H. Chilton, eds. McGraw-Hill Book Company, New York. 1973.

5.1.2 Types of Flow Recorders

Flow recorders are required for continuous monitoring for either permit conditions or process control.

To perform such a secondary function as recording or flow control, the indicator used must be coupled with a transmitter prior to being recorded. Magnetic couplings were developed to sense float position and can be used for any flow metering device that uses a metal float for sensing the head of the system.

Most transmitters are pneumatic or electronic. The position of an indicator must be connected to one of these types of central signals for recording and controlling. Both types of signals can be adaptable from a magnetic coupling. Pneumatic transmitters have the usual fullscale output of 15 psig. A 10 percent flowrate output is 4.2 psig. At no flow, the output is 3 psig. Electronic transmitters are most commonly arranged for a linear output, ranging from 1 to 5, 4 to 20, or 10 to 50 mA dc -- covering a flow range of 0 to 100 percent. The pneumatic or electronic signal from a transmitter can be sent to either a recorder or controller or both. The most common recorders are discussed below.

Strip Chart Recorder--

The strip chart is usually designed with rectangular coordinates, with time being the "y" axis (or ordinate) and the "x" axis (or abscissa) as the variable. A recording pen arm is normally used, but a hammer with special strip paper that makes a series of marks is sometimes used. The chart can also be a multipen type in which two or more items could be recorded (flow, temperature, etc.).

Circular Chart Recorder--

The circular (or round chart) has time numbers at its extreme circumference and a series of concentric circles on which the values are marked. The recording chart usually covers a 24-hour period and has a single function marked on it, but it can also be a multipen type in which two or more items could be recorded (flow, temperature, etc.).

Both recorder types require frequent attention to insure that ink is flowing freely, that the chart time markings are calibrated to true time, that the chart paper is moving, and that the instrument is working. Circular charts must be changed daily to avoid confusion.

5.1.3 Flow-Metering Problems

The problems that can be encountered are broken down by the various devices used.

Weirs--

- Weir crests or notches not chamfered
- Weir covered with debris or scale
- Weir crests not flush with the weir plate
- Weir notch not properly porportioned with respect to the sides or bottom with respect to the head of flow
- Measurement of the head on the weir taken at a point less than 4 times the maximum head on the crest or notch
- The cross-sectional area of the approach duct, flume, or sluice less than 8 times that of the overflow area at the crest or notch at a distance of 15 to 20 times the head upstream of the weir
- At low flows, especially in a wide channel, small errors in measuring the height of the overflow cause large errors in calculated flow.
- Improper ventilation of weir resulting in the formation of a vacuum on the underside of the falling stream.

Parshall Flume--

- Incorrectly designed for maximum flow, resulting in inaccuracy in flow reporting
- Not properly leveled during installation
- Insufficient flow causing buildup in the flume

Open-Flow Nozzles--

- Approach insufficient in length (8 times the diameter)
- Pipe not horizontal with nozzle
- Line size insufficient for flow being handled

Other Basic Devices--

- Thin plate square or sharp-edged orifice

  Orifice no longer square or edge not sharp
  Used in line other than clean fluids

Location of tap holes
Difficult to inspect
Excessive change in flow rates for installed orifice

- Flow nozzle

  Improper location of tap holes (1 diameter upstream, 1/2 diameter downstream)
  Improper ratio of throat diameter to length of nozzle
  Deterioration or change in smoothness of approach to tangency
  Difficult to inspect
  Hard to remove
  Change in flow or type of fluid passing through the nozzle

- Venturi tube or Dall tube

  Solids content too high
  Hard to remove
  Difficult to inspect

Rotameters--

- Flow rate not compatible with flow meter installed
- Pressure problems
- Temperature problems
- Resistant to corrosion
- Accuracy problems
- Fluid not clean

Orifice and Tapered Plug Meters--

- Readings not highly accurate
- Metal fines in flow material (affects the float magnet and follower magnet)
- Change in flow being handled

Piston-Type Meters--

- Changes in viscosity of liquid
- Fluid not free of foreign materials
- Strainer upstream of meter missing or worn
- Meter mounting greater than 5 degrees off of vertical

Magnetic Flow Meters--

- Changes in electrical conductivity of fluid flows
- Flow tube material not compatible with flow material
- Short circuit (may occur if the insulated lining material of a stainless steel tube wears through)

Turbine Meter and Vortex Velocity Meter--

- Fluid contains debris
- Maintenance problems on rotor

Lobed-Impeller, Sliding-Vane, and Retracting-Vane Rotary Flow Meters--

- Slip at low flows
- Debris in flow
- Maintenance and seal problems

5.1.4 Effective O&M Practices

Effective O&M practices can be achieved through inspection and preventive maintenance if the design of the installation permits easy access and removal. On continuous production units it may be necessary to have a second unit tied into a bypass system to permit servicing of the first unit. Thus, each side of the unit would have valves to permit the removal of a unit for inspection, maintenance, or replacement. When operations are not continuous, inspection and maintenance can be performed when the unit is not in operation.

Weirs--

Weirs must be maintained in the following manner or readings will be incorrect.

- The surface facing and the stream or flow must be smooth and perpendicular to the flow in the duct, flume, or sluice.

- The edge of the notch, where it intersects the flow of incoming water, should be sharp and right-angled.

- If the thickness of the weir is such that it exceeds 2 mm (0.08 inch), the downstream edges of the notch in excess of 2 mm should be chafered at an angle of 45 degrees or more.

- The distance of the notch from the bottom of the duct, flume, or sluice (water or fluids low point) should be at least twice the depth of the water above the notch's crest, and in no case less than 1 foot.

- The distance of the notch edge from the side of the weir (the width of the weir being the same width as the flume or sluice or duct) should be no less than twice the depth of the water above the notch's crest, and in no case less than 1 foot.

- Areas in vicinity of the weir, and especially at the notch, must be kept clean.

Parshall Flume--

- Longitudinal and lateral axes of the flume floor must be level.
- Sidewalls must be parallel and throat dimensions close to design tolerances for maximum flow.
- Flow distribution must be uniform in the upstream convergence section.
- Head measurement must be properly located.
- Maximum and minimum flows must be compatible with flume design.

Open-Flow Nozzle--

- Pipe diameter and nozzle must be for the flow ranges being handled.
- Flow pipe and length of pipe must be level and of sufficient length to tolerate flow changes.

Other Basic Devices--

- Thin plate square or sharp-edged orifice

  Must be used in clean fluid flows.
  Orifice plate must be inspected periodically for trueness.
  Must be easy to inspect and replace.
  Proper orifice must be used for flow ranges.

- Flow nozzle

  Must be checked periodically.
  Must be easy to inspect and replace.
  Proper nozzle must be used for flow ranges.

- Venturi tube or Dall tube

  Must be checked periodically.
  Must be easy to inspect and replace.

Rotameters--

- Periodic inspection is required.
- Must be easy to inspect and replace.

Orifice and Tapered Plug Meters--

- Must be checked periodically.
- Must be easy to inspect and replace.

Piston-Type Meters--

- Periodic inspection is required.
- Strainers must be inspected and replaced as necessary.
- Vertical alignment of meter is critical.
- Must be easy to inspect and replace.

Magnetic Flow Meter--

- Periodic inspection is required.
- Must be easy to inspect and replace.

Turbine Meter and Vortex Velocity Meter--

- Periodic inspection is required.
- Must be easy to inspect and replace.

Lobed-Impeller, Sliding-Vane, and Retracting-Vane Rotary Flow Meters--

- Periodic inspection is required.
- Frequent maintenance is required.
- Must be easy to inspect and replace.

REFERENCES FOR SECTION 5.1

1. U.S. Environmental Protection Agency. Handbook for Monitoring Industrial Wastewater. August 1973.

2. Considine, D. M. Process Instruments and Controls Handbook. McGraw-Hill Book Company, New York. 1974.

5.2 PH METERS

The pH analyzer is used more than all other types of continuous analytical instruments combined.[1] In the steel industry, they are used extensively for such purposes as monitoring the pH of the recycle water, the feed to ammonia stripping columns, and the biological treatment systems and for checking the pH at outfalls to make sure that it is within the permitted limits.

A pH meter contains a glass electrode that develops a predictable electrical potential directly related to the hydrogen ion concentration of the solution in which it is submersed. The actual mechanism by which certain types of glass develop this potential is an extremely complex one and will not be discussed here. The pH meters either must be calibrated at their operating temperature or they must contain a temperature sensor and circuit that corrects for temperature. This is necessary because pH meters measure only the concentration of hydrogen ions actually dissociated in a solution, and the amount of dissociation increases as water temperature increases. This dissociation increases the quantity of hydrogen and hydroxyl ions equally. This type of dissociation does not alter the acidity of the solution; however, since pH meters only read hydrogen ion concentrations, they will record a change in pH as the temperature changes, unless their reading is corrected for these temperature changes.

5.2.1 pH Meter Problems

The output of the pH electrode tends to drift with age and use. This is a drift, not a drop or sudden change.

The pH probe is subject to fouling if the wastewater contains solids, and fouling of the electrode can cause serious errors in its output.

Care must be taken when storing the glass electrodes outside of water. If they are stored dry for long periods of time, the pH readings will continue to drift for periods of 24 to 48 hours when they are reimmersed in water because it takes this long to reestablish an equilibrium on the glass surface.

Greasy films can cause drift if they are adsorbed onto the surface of the electrode. Also, strong acids and caustic solutions can permanently alter the external surface of the glass.[1]

The glass electrode is fragile and subject to breakage.

5.2.2 Effective O&M Practices

Electrode drift can be corrected by periodic calibration. Calibration is accomplished by immersing the electrodes in a known pH solution and adjusting the electrical signal corresponding to that solution's pH.[2] The frequency of calibration depends on the pH system being used and the service, but some plants calibrate daily. When they are in continuous use, pH electrodes deteriorate over time and thus require more frequent calibration as time and service increase. Periodic replacment of the electrodes makes the need for calibration less frequent.

Suspended solids building up on the electrode must be cleaned off before they affect the electrode output. This can be done by removing the electrodes for cleaning, or in some cases, by flushing the line containing the electrode with process water. Again the specific application of the electrode will determine the required frequency and method of cleaning.

The electrode should be kept wet. This requires keeping water around the electrode while it is in service and storing the electrode in water when it is taken out of service.

Breakage can only be prevented by careful handling of the electrode. Spare electrodes should always be kept in stock.

REFERENCES FOR SECTION 5.2

1. Considine, D. M. Process Instruments and Controls Handbook. McGraw-Hill Book Company, New York. 1974.

2. U.S. Environmental Protection Agency. Background Document for Modification of pH Effluent Limitations Guidelines and Standards for Point Sources Required by NPDES Permit to Monitor Continuously Effluent pH. EPA-440/2-80-083, 1980.

5.3 LEVEL CONTROLLERS

Level controllers are used throughout steel wastewater treatment systems. Because most of the wastewater handled is neither flammable nor highly corrosive and the pressure is generally atmospheric, these level control devices tend to be fairly simple. Level control inherently depends on level measurement; therefore, level indicators are discussed in this section. Actually, the simplest kind of level control is an indicator that the operator reads to ascertain the adjustments necessary to maintain a desired level.

5.3.1 Kinds of Level Controllers

Dip Sticks--

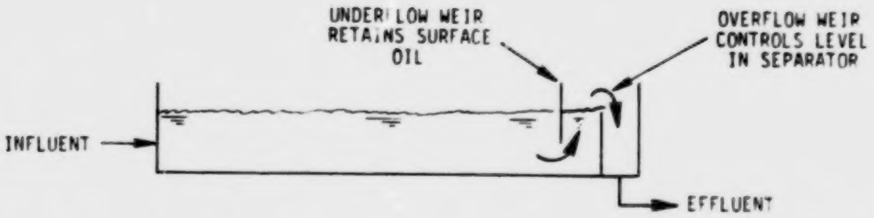
The dip stick, the simplest level-measuring instrument, can be a ruler, rope, or chain that has been calibrated. Large settling basins are sometimes used for settling wastewater from the rolling mills. Periodically, these basins have to be pumped out and dredged. Because these basins slowly fill up during use, their actual depths must be checked by going into the basin on a boat and using a dip stick to take soundings at various locations. A grid should be laid out over the basin so that the soundings are taken at regular intervals. Used properly, the dip stick is one of the most accurate level-measuring devices.

Weir--

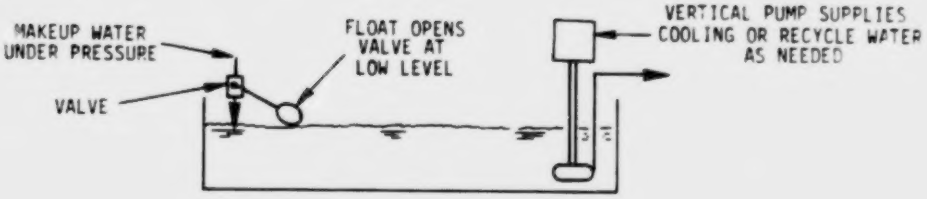
A weir controls the water level in a vessel or lagoon by allowing the water to flow out of the vessel when it rises above a certain point. Weirs are usually adjusted physically by raising or lowering the weir plate. Weirs are used to control the level in clarifiers and in some types of water-oil separators. Figure 5.3-1 shows how a weir is used in the latter application.

Float Valve--

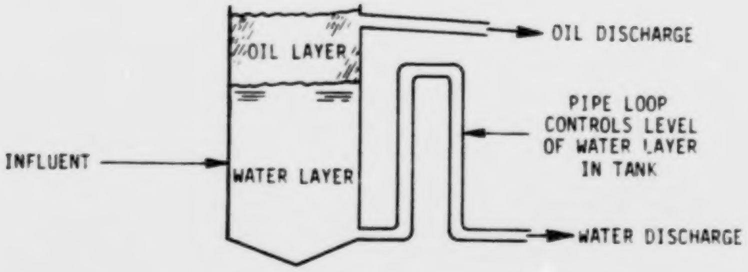
Household flush toilet tanks use a float valve to maintain the level in the tank. This device consists of a valve that is opened and shut by the up-and-down motion of a float attached to the valve actuator. Figure 5.3-1 shows a float valve as it is commonly used in a cooling tower or recycle water basin. Water is pumped out of the basin as needed by the process.


UNDERFLOW WEIR RETAINS SURFACE OIL
OVERFLOW WEIR CONTROLS LEVEL IN SEPARATOR
INFLUENT
EFFLUENT

WEIR LEVEL CONTROL ON OIL/WATER SEPARATOR


MAKEUP WATER UNDER PRESSURE
FLOAT OPENS VALVE AT LOW LEVEL
VERTICAL PUMP SUPPLIES COOLING OR RECYCLE WATER AS NEEDED
VALVE

FLOAT CONTROL VALVE ON MAKEUP WATER SYSTEM


OIL LAYER
OIL DISCHARGE
PIPE LOOP CONTROLS LEVEL OF WATER LAYER IN TANK
INFLUENT
WATER LAYER
WATER DISCHARGE

OIL DECANTER

Figure 5.3-1. Simple level control systems.

Leaks, evaporation, and other types of losses require the addition of makeup water. A float valve will automatically add water as necessary to maintain the proper level in the basin. The valve itself must be connected to a water line that is pressurized. As the level falls, the float drops and opens the valve. As the valve adds water, the basin level and hence the float rises. When the float rises to a preset point, it turns the valve off.

Oil Decanter--

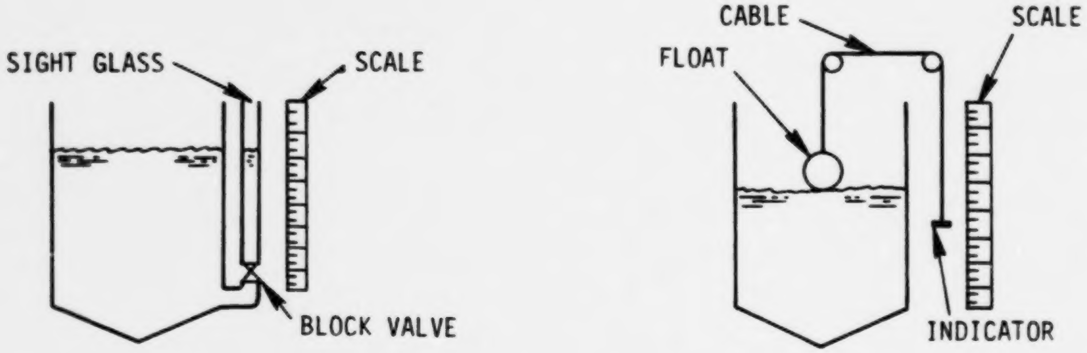
Figure 5.3-1 shows a tank used to decant oil. A pipe loop connected to the bottom of the tank controls the maximum water level that can exist in the tank. Because oil is lighter than water and the pipe loop contains only water, the oil level in the tank can be above the top of the pipe loop. A gravity overflow line is installed on the tank above the pipe loop to remove oil as it accumulates. Note that if the tank contains only water, the water level in the tank will be at the top of the pipe loop. The location of the gravity drain and top of the pipe loop depend on the specific gravity of the oil being separated.

Sight Glass--

The sight glass (or gauge), shown in Figure 5.3-2, is commonly used to indicate the level in a tank. This gauge consists of a glass or plastic tube connected to the bottom of the tank and strapped up the side of the tank. A scale, which is usually a large ruler, is located near the sight glass. The liquid level in the sight glass will be the same as that in the tank. These sight glasses are as accurate as the calibration marks on the gauge.[1] This type of gauge is typically used on polymer or other chemical additive tanks. The operator checks the tank level daily to ensure that a sufficient supply of material is available. Also, by timing the rate of fall of the level in the tank, the operator can determine the rate of addition of material to the process.

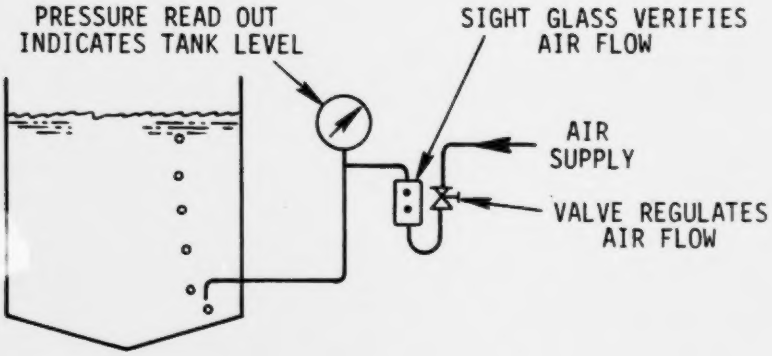
Float and Cable--

Figure 5.3-2 shows a float and cable level indicator. This indicator, like the sight glass, shows the tank level on a scale mounted by the tank. A float rides on the surface of the liquid in the tank. A cable and pulleys connect the float to an indicator that moves up and down a scale mounted outside the tank as the float moves up and down inside the tank. The float


SIGHT GLASS
SCALE
BLOCK VALVE
CABLE
SCALE
FLOAT
INDICATOR

SIGHT GLASS LEVEL INDICATOR

FLOAT AND CABLE LEVEL INDICATOR


PRESSURE READ OUT
INDICATES TANK LEVEL
SIGHT GLASS VERIFIES
AIR FLOW
AIR
SUPPLY
VALVE REGULATES
AIR FLOW

BUBBLE TUBE LEVEL INDICATOR

Figure 5.3-2. Common level indicators.

and cable can be used in oily liquids that might stain the inside of a site glass and make it difficult to read.

Bubbler Tube--

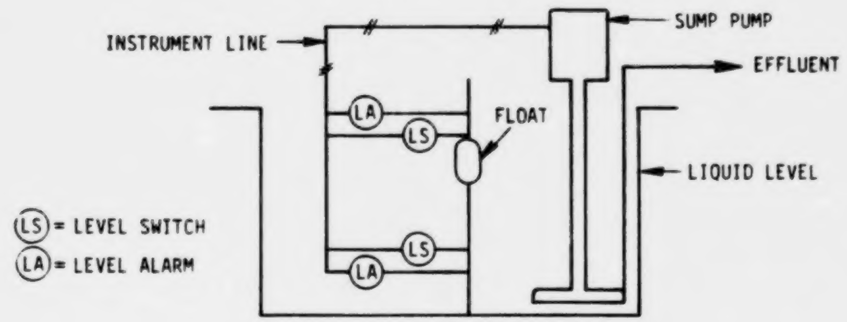
The bubbler tube or air purge system is shown in Figure 5.3-2. This commonly used device actually measures the pressure at the bottom of the tank and converts this value to a level reading. A tube at the bottom of the tank is connected to a pressure sensor. The other side of the pressure sensor is open to the atmosphere so that changes in atmospheric pressure will be cancelled out. To keep the tube from plugging, a small amount of air, typically one cubic foot per hour, is injected into the tube and bubbles out the end of the tube into the tank. The air flow is controlled by a needle valve. A small sight glass filled with a low-volatile oil is usually located near the needle valve so the operator can judge the air flow rate by noting how frequently bubbles rise in the sight glass. In addition to providing a local reading, the pressure indicator can send a signal to a control panel or operate a control valve. This very reliable system is used for both local and remote readouts of level, as well as in automatic level control systems.[2,3]

Float-Switch Sump Level Control--

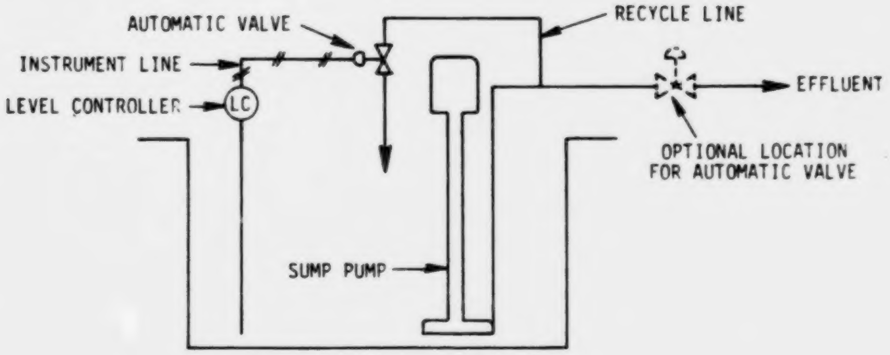
Controlling the level in sumps is a common problem in iron and steel waste treatment facilities. A typical example is sump level control in the rolling mill sumps. Here the water flow can vary with production from no flow to a very high rate of flow. Figure 5.3-3 shows a sump level control using a float control with high and low level switches. When the liquid reaches high level, the float contacts a microswitch that turns the pump on. The pump will continue to run and empty the sump until the level and the float drop to the low-level switch. Level alarms are usually added on either side of the level switches. If for any reason the liquid level goes beyond the range of the level switches, an alarm will sound. In this type of operation the pump is either on or off.

Level Control Equipped With a Control Valve--

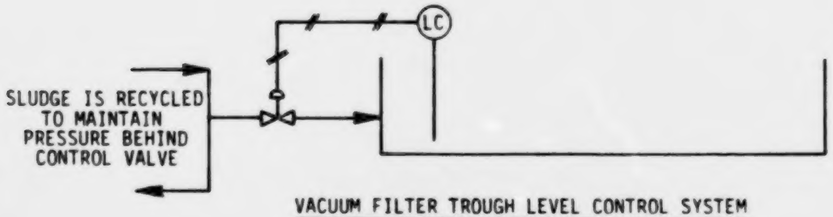
If the process requires a constant level, a continuous level control indicator can be coupled with a control valve to provide a fairly constant


INSTRUMENT LINE
SUMP PUMP
EFFLUENT
FLOAT
LIQUID LEVEL
LA
LS
LS
LA
LS = LEVEL SWITCH
LA = LEVEL ALARM

SUMP LEVEL CONTROL USING A FLOAT AND LEVEL SWITCHES


AUTOMATIC VALVE
RECYCLE LINE
INSTRUMENT LINE
EFFLUENT
LEVEL CONTROLLER
LC
OPTIONAL LOCATION FOR AUTOMATIC VALVE
SUMP PUMP

SUMP LEVEL CONTROL USING A CONTROL VALVE


LC
SLUDGE IS RECYCLED TO MAINTAIN PRESSURE BEHIND CONTROL VALVE

VACUUM FILTER TROUGH LEVEL CONTROL SYSTEM

Figure 5.3-3. Level control systems.

level. Figure 5.3-3 shows such an arrangement for the trough of a drum filter. The swings in level that exist when level switches are used could not be tolerated in this application. The slurry is recycled past the control valve so there is always slurry under pressure downstream of the control valve. As the level in the trough deviates from the set point, the level indicator sends a signal that opens or closes the control valve to maintain a constant level.

Figure 5.3-2 also shows how this arrangement can be used to maintain the level in a sump. In this case, the level controller can actuate a control valve on a recycle line at the pump discharge or it can be wired to a control valve in the pump discharge line. The recycle is sometimes advantageous if suspended solids are present in the sump. The turbulence caused by the recycle will agitate the sump and help keep solids in suspension.

5.3.2 Effective Operation and Maintenance Practices

Dip Sticks--

Because of their simplicity, dip sticks are almost taken for granted, but they are not infallible. If the dip stick is pushed into the liquid too quickly, water can splash up on the stick and produce an erroneously high reading. Inserting the dip stick at an angle also can produce a high reading, as will any turbulence or waves in the water when the dip stick is used. Conversely, if the stick does not touch bottom, a low reading results.

Weir--

Weirs are also very simple and almost trouble-free. The top of a clarifier weir must be perfectly level to achieve proper operation. In addition to controlling level, the weir on a clarifier must provide uniform flow over the entire length of the weir; otherwise turbulence will be created that can upset the clarifier operation. Uneven weir heights can result from improper installation or the settling of the clarifier after it has been placed in operation. The operator should check the clarifier weir visually from time to time to ensure that flow over the weir is uniform at all points.

Float Valve--

Float valves are very reliable and low in cost, but their moving parts make them prone to failure. In applications where the valve is open and shut frequently, the valve seat tends to wear and cause the valve to leak. The float also can develop a leak and lose its buoyancy.

Sight Gauge--

Sight gauges are fragile and must be protected from physical damage. The tank could empty if the glass is broken. Protection is sometimes provided by building a wire cage around the sight glass. A shutoff valve at the bottom of the sight glass where it enters the tank is necessary so the sight glass can be disconnected for repair or replacement. The operator should make sure that the scale mounted beside the sight glass is aligned properly. The scale is generally a wooden board with lines and numbers painted on it. As they weather, these boards can become difficult to read. They should be repainted as necessary so the operator can read them easily. The sight glass must be cleaned as necessary to maintain its transparency, and this type of gauge will not work well with a viscous liquid that tends to adhere to and stain the walls of the sight glass.

Float and Cable--

The float and cable system is generally very reliable. As in the case of the sight glass, the scale must be kept painted and in good repair. This is a mechanical system and can be hampered if the float springs a leak, a pulley seizes or gets out of alignment, or the cable breaks.

Bubbler Tube--

Because the bubbler tube actually measures pressure, the density of the liquid in the vessel must be constant for this system to work consistently. A flow of air must always be maintained or the tube can foul and plug.

Float Switch Sump Level Controller--

The float in this sytem usually rides up and down a vertical rod that goes through the center of the float. Trash or corrosion can cause the float to hang up on the rod. As in the case of other float systems, the float can also spring a leak and lose its buoyancy. Since this level control system operates pumps in an on-off mode, it must be designed and installed so it will not cycle the pump too frequently. Frequent on-off operations can greatly shorten the life of the pump motor.

Level Control Using A Control Valve--

This system can operate very reliably if it is designed and installed properly. If the control valve is not sized properly, it can overcompensate and put the system into a state of oscillation. When the valve receives a signal that the level is low and opens, a valve that is too large will immediately drive the liquid level up and quickly receive a signal that the level is too high. The valve will then close and overcompensate in the other direction. When this system is installed on a sump, as shown in Figure 5.3-3, putting the control valve in the recycle line has the additional advantage of agitating the contents of the sump. The recycle mode has the disadvantage of not being able to shut off the flow from the pump completely; thus, a low-level pump shutoff control should be added. Also, the pump on the recycle system always runs at maximum output, which maximizes energy costs for operating the pump. If the control valve is in the pump discharge line, it can control flow from zero to maximum pump output capacity. This poses a danger in that if the sump level is low and the control valve in the discharge line shuts off, the pump could burn out if it keeps running. The designer can protect against this possibility by installing a recycle line between the pump and the control valve. Usually a restrictive orifice is placed in the recycle line so the pump will always induce enough liquid flow to keep the pump from burning out.

REFERENCES FOR SECTION 5.3

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2. Sanks, R. L. Water Treatment Plant Design for the Practicing Engineer. Ann Arbor Science Publishing, Inc. Ann Arbor, Michigan. 1979. p. 451.

3. Smith, C. L. Liquid-Measurement Technology. Chemical Engineering, 85(8):155-164, April 3, 1978.

5.4 OXIDATION-REDUCTION POTENTIAL

Measurements of oxidation-reduction potential (ORP) are often used in monitoring the progress of chemical reactions. Therefore, such measurements can form a basic component of process control. This technique has seen considerable use in controlling the chlorine addition rate in processes utilizing chlorine as an oxidant for ammonia and cyanide.

The ORP is defined as the electromotive force that results when a noble metal electrode and a reference electrode are immersed in a solution. The inert ORP electrodes measure the ratio of the concentration of the oxidized solution to that of the reduced species in the process reaction. The ORP measurement is usually displayed as millivolts (mV) on a pH meter. Any of the different types of metallic electrodes may be used, but in all cases the ORP follows the general properties described by the Nernst equation, which can be found in most upper-level chemistry texts.

The first type of electrode consists of a metal in contact with a solution of its own ions. The metal is in the reduced state and its ions in the oxidized state. The second type of electrode consists of a metal coated with a sparingly soluble salt of the metal in contact with a soluble salt of the same ion, e.g., silver/silver chloride in a solution of potassium chloride. The third type of electrode consists of an inert metal in contact with a solution containing both the oxidized and reduced states of an oxidation-reduction system. Platinum and gold are the most common electrodes of this type. The selection of the electrode must be made so that the materials comprising the electrode can withstand any corrosive effects exhibited by the waste to be monitored.

Monitoring of ORP in a chlorination process (e.g., alkaline chlorination -- see Section 3.8) usually involves the incorporation of the silver/silver chloride electrode. The electrode can be placed in one or two locations in the process. The first location can be in the chlorine mixing chamber to monitor the ammonia and cyanide oxidation reactions while the chlorine is reduced. The second can be in the effluent chamber to monitor the effluent for the presence of free chlorine. Readings taken with the electrode placed in the mixing chamber will show a greater positive ORP because large amounts of chlorine are added to reduce the pollutants. The effluent chamber location is used only to observe free chlorine and will produce a lesser positive ORP.

5.4.1 ORP Measurement Problems[1]

The problems associated with ORP measurement are due to interfering substances in the wastewater. This can lead to one of two general operating problems: 1) incorrect measurement of ORP or 2) incorrect interpretation of measurements. The ORP electrodes are generally reliable and not subject to interference from color, turbidity, colloidal matter, and suspended matter. The interferences affecting ORP measurement are discussed briefly below.

- The ORP is sensitive to wastewater temperature. Only minor variations occur, however, and service temperature correction, while possible, is not performed.

- Measurement of ORP compares closely to that of pH. If one or more of the ensuing reactions involves the transfer of hydrogen ions (as in the case of alkaline chlorination), then ORP measurement becomes pH dependent. The ORP displays an inverse relationship with pH, with increasing pH causing a decrease in ORP.

- Reproducible ORP results cannot be obtained exactly for reactions that are not reversible. Thus, overdoses of the oxidizing agent must be added to ensure complete oxidation.

- A brightly polished metal electrode surface is required for accurate ORP measurement. It is possible for the electrode to absorb material from the waste stream and become contaminated such that a memory affect is observed. Subsequent ORP readings are thereby influenced by the absorption of contamination into the electrode. This is especially true when very low concentration measurements are desired immediately after a measurement has been made in a relatively concentrated wastewater.

- The metallic surface may absorb organic compounds and become poisoned by cyanides and sulfides in the wastewater. This is less of a concern when the electrode is placed in the effluent chamber, as these materials are completely oxidized by the time the wastewater reaches this chamber.

- All oxidation-reduction reactions will display an ORP. The ORP resulting from several reactions in the wastewater cannot be assigned to any one particular reaction. In a control situation, chlorine will be added based on an ORP set point. This set point, if measured in the mixing vessel, must account for other reactions that may occur and therefore must be determined experimentally.

5.4.2 Effective O&M Practices

Measurement Device--

Although of less importance than the electrodes themselves, minor attention must be given to the meter, usually a pH meter, used to display the ORP measurement. The meter must be used in the millivolts mode for ORP. The correct electrode and reference device should be securely attached to the meter. The display will account for the difference in the potential of the electrodes. This reference point must therefore be determined if the ORP of a wastewater is calculated rather than determined experimentally. For remote ORP measurement, shielded cable is required.

Electrode Maintenance--

A suitable electrode support is needed to protect the electrodes. If only intermittent measurements are made, the immersible ends of the electrodes should be kept in water in between readings. Before an electrode is placed in service, oily residues should be removed with a detergent. Subsequent daily cleaning is also recommended. Electrodes can be cleaned with chromic acid, aqua regia, hydrochloric acid, or nitric acid. Manufacturer procedures should be followed. Suddenly changing the pH of a solution in which the electrodes are immersed provides an easy check of electrode response. A sharp inverse response in millivolts should be observed when the pH is changed. A direct response indicates that the electrode polarity is reversed, and a slow response indicates cleaning is necessary.

General Operating Practices--

Because the ORP of a process varies with pH, both values must be recorded simultaneously. Different electrodes are required for the measurement of ORP and pH, even though the same meter can be used. If pH varies in the wastewater, the desired ORP must be determined for various pH values.

The ORP measured in a wastewater treatment process will vary depending on the electrodes used and the actual treatment chamber monitored. Use of the silver/silver chloride electrode in the chlorine mixing vessel will usually require an ORP of +700 to +800 mV to ensure complete oxidation of pollutants. Much lower ORP is required to measure free chlorine in the effluent chamber. Regardless of the location of the electrodes, mixing must be completed prior to ORP measurement to ensure that a representative reading is taken and to avoid potential poisoning of the electrode by an unmixed portion of the wastewater.

REFERENCE FOR SECTION 5.4

1. American Society for Testing and Materials. Standard Practice for Oxidation-Reduction Potential of Water. In: 1979 Annual Book of ASTM Standards, Part 31, Water. Library of Congress Catalog Card No. 40-10712. 1979.

5.5 INSTRUMENTATION

Previous sections have contained discussions on flow meters, pH and ORP meters, and level controllers. This section briefly covers some of the other instruments used in iron and steel wastewater treatment systems.

5.5.1. Additional Instrumentation

Pressure Gauges--

Most pressure gauges are either diaphragm, bellows, or Bourdon tube gauges.[1] All are very reliable. The most common place to install a pressure gauge is on a pump discharge. When an operator starts a pump, the gauge reading indicates whether the pump is primed and operable. The operator should be familiar with the discharge pressure of the pumps under his/her management. A higher-than-normal pressure indicates that the discharge line is plugged or valved off. A lower-than-normal pressure may indicate a worn pump impeller, a reduction in pressure drop in the discharge line, or some other problem with the pumping system.

The use of vacuum gauges on vacuum filters helps the operator determine filter performance. A higher-than-normal vacuum may indicate that the filter cloth is becoming blinded; whereas a lower-than-normal vacuum may mean a torn filter cloth, air leakage somewhere in the system, or a problem with the vacuum pump.

Amp Meters--

Amp meters measure the power output of motors. One plant used amp meters on sludge pumps to help judge whether they were operating properly. An atypical amp meter reading would only tell the operator that something unusual was happening. The operator would then have to determine the cause of the problem. One steel mill used amp meters on aerators in their biological treatment plant. These aerators consisted of fixed impellers on the surface of the biological pond. If the pond level fell and the amount of aeration decreased, the amp reading would go down. In this case the amp reading correlated with the amount of aeration occurring.

Alarms--

Alarms are usually installed at critical points in the process to warn the operator that a malfunction has occurred or is about to occur. Alarms can be added to flow meters, level controllers, and pH recorders. A typical example would be high- and low-level alarms on a sump equipped with a discharge pump and a level control system.[2] The discharge pump might be set up to come on at a high liquid level and shut off at some low liquid level. The alarm points would be set at levels above and below the pump control switches. If the pump motor should burn out or an operator should inadvertently close a block valve on the pump discharge, the pump would be unable to pump out the sump. In either case, the pump would not be activated by the sump high-level control signal, and the water level would keep rising. At some higher point the rising water would activate the alarm to warn the operator that the sump was about to overflow. A low level danger could occur if the pump controller were to fail and the pump would continue to run after the level dropped below the normal pump shutoff point. In this case an alarm would sound to tell the operator that the sump level was low. Without this information the pump might run dry and burn out.

Dissolved Oxygen Probes--

Dissolved oxygen probes can be used to measure the oxygen content of biological treatment ponds. The oxygen content of biological ponds must be at least 1 to 2 mg/liter to maintain viable organisms.[3] Because the calibration and use of these instruments vary with each manufacturer, the manufacturer's instructions should be followed. Most of them claim a precision of 0.1 mg/liter with ±1 percent accuracy.[4]

Turbidity--

According to the literature, turbidity meters have been used to monitor the effluent from sand filters or from the treatment plant itself.[2] Several steel mills also have tried using turbidity meters on clarifier effluent. These meters are designed to sound an alarm if the turbidity increases, which indicates that the effluent is high in suspended solids.

5.5.2 Effective Operating and Maintenance Practices

Pressure Gauges--

Pressure gauges tend to plug in slurry service. The plant can minimize this plugging by inserting a diaphragm in the line just ahead of the pressure gauge. Normally, a liquid (such as glycerin) fills the space from the diaphragm into the Bourdon tube of the pressure gauge.

Pressure gauges should always be installed with a shutoff valve, and a vent valve should be placed between the shutoff valve and pressure gauge. This kind of installation makes it possible to isolate and vent the pressure gauge so it can be serviced, replaced, or checked to see if it is working properly. The pressure should return to zero when the gauge is vented.

Amp Meters--

One plant had tried to use an amp meter instead of a torque meter on their clarifier rake mechanism because they thought the torque meters were fragile and subject to malfunction. They discovered that the mechanical advantage between the motor and the rake was so high (several thousand to one) that the rake could hang up and damage before the amp meter indicated a problem.

Dissolved Oxygen Meters--

If the dissolved oxygen meter in the biological pond indicates that the oxygen level is too low, the first remedial step is to increase the effectiveness of the aerator. One plant had a problem with low dissolved oxygen in the bottom portion of the bug pond when the aerator was running well. The problem was solved by inserting compressed air lines into the pond. These lines not only provided additional oxygen but also produced better mixing.

Turbidity Meters--

The steel mills visited have had very little success with the use of turbidity meters on clarifier effluents. These meters tend to freeze and fail in the wintertime. The lack of success with turbidity meters may have resulted partially from lack of attention.

REFERENCES FOR SECTION 5.5

1. Smith, C. L. Liquid Measurement Technology. Chemical Engineering. McGraw-Hill Book Company, New York. April 3, 1978. p. 164.

2. Sanks, R. L. Water Treatment Plant Design for the Practicing Engineer. Ann Arbor Science Publishing, Inc., Ann Arbor, Michigan. 1979. pp. 425, 452.

3. Clark, B. J., and M. A. Ungersma. Wastewater Engineering. McGraw-Hill Book Company, New York. 1972. p. 490.

4. U.S. Environmental Protection Agency. Manual of Methods of Chemical Analysis of Water and Wastes. EPA-625/6-74-003, 1974.

SECTION 6

MANAGEMENT PRACTICES FOR EFFECTIVE SYSTEM OPERATION

Most of the effective O&M practices described in this report are examples of actual practices observed at several steel mills. The information was collected by interviewing treatment system operators, maintenance personnel, and environmental department staff.

6.1 ORGANIZATION/COMMUNICATION

Effective O&M practices at a wastewater treatment system are those that can keep the system operating at its optimum (design) performance with minimal downtime.

It is management's responsibility to initiate and maintain an O&M plan. Although most of the following O&M practices (i.e., communications, operator training, staffing, recordkeeping, preventive maintenance, and treatment system auditing/evaluation) are probably implemented to some extent at all plants, their effectiveness depends on the degree to which they are practiced, how carefully they are practiced, and whether they are fine-tuned periodically (if necessary) to achieve optimum results.

The plant visits made during this study indicate that the management organization for water pollution control has much to do with successful communications and with obtaining the cooperation necessary to solve problems expeditiously. Generally, the management structure at the plants visited is as follows:

- The utilities (power and fuels) department is responsible for operating the wastewater treatment systems.
- The process department, which is responsible for the steel mill process operations, assumes at least part of the responsibility for delivering wastewater to the treatment systems.

- The environmental department keeps all pertinent personnel informed of current and expected water regulations that will have an impact on the plant. This department serves as a go-between for the plant's pollution control section of the utilities department and the regulatory agencies and is responsible for all correspondence with the agencies.

Table 6-1 shows a breakdown of which departments actually operate (O) or maintain (M) the process wastewater treatment systems at the plants visited.

TABLE 6-1. DEPARTMENTS THAT OPERATE AND MAINTAIN WASTEWATER TREATMENT SYSTEMS AT VISITED PLANTS

	Utilities department		Process department		Environmental department	
	O	M	O	M	O	M
Blast furnace	3	1		2		
Coke plant:						
Biological treatment	2	1	1	2		
Ammonia still			3	3		
Hot strip mill:						
Scale pits	1		4	5		
Clarification/sedimentation	5	1		4		
BOF	3	1		2		
	14	4	8	18	0	0

Observation of the workings of these departments (particularly process and utilities) indicates that pollution control needs are met most effectively when the utilities department has both a maintenance staff and an operating staff. It also appears that it would be advantageous for the utilities department to operate some equipment that has typically been operated by the process department (e.g., scale pits), or if that is not possible, to make sure that a strong spirit of cooperation is established between the two departments. This is especially important when the operation of the control equipment is greatly affected by the operation of the process equipment (e.g., coke byproduct plants). For example, an effective arrangement at one coke plant involves a byproducts engineer and a process supervisor (responsible for the biological treatment system) who work hand-in-hand because both are in the same department and have a common goal--the optimum performance of the byproducts plant/biological treatment system.

When a utilities department does not have its own maintenance staff and has to rely on maintenance help from production departments, there is competition for maintenance resources. If production needs are greater, chances are good that the pollution control department will have to wait until maintenance personnel are available.

An alternative to the utilities department having its own maintenance staff is to have operators perform some of the day-to-day maintenance, such as routine equipment oiling/lubrication and minor pump repairs. This approach seemed to work well at two plants. With the burden of routine maintenance taken off the maintenance department, they are able to make time for larger repair jobs requested by the utilities department.

6.1.1 Communication

Proper communication is essential to effective O&M. Figure 6-1 illustrates effective and ineffective communication structures, both of which were noted during the plant visits. In the effective system, all personnel connected in some way to the generation of wastewater and its treatment have good communication lines. In the plants visited, most of the treatment systems were operated by the utilities department, so the utilities supervisor is a key person in making the communication system work.

In the example shown, strong two-way communication lines (indicated by the thick dashed lines) are required between the utilities supervisor and his operators and maintenance personnel. Frequent contact must exist between the supervisor and operators to keep the supervisor posted on the day-to-day operation of the treatment systems. At the plants visited, direct communication took place between operators and supervisors (face to face or by telephone) anywhere from once an hour to once a shift. Indirect communication (use of logs, records, computer terminals) occurred at about the same frequency.

Effective communication allows the utilities supervisor to stay on top of things and to make decisions more quickly when a problem arises. Frequent communication seems to make the operators realize the importance of their jobs. Only through effective communication ties between operators, supervisor, and maintenance personnel can problems be brought to the attention of the necessary parties. These open communication lines also allow discussion and consideration of alternate solutions to problems.

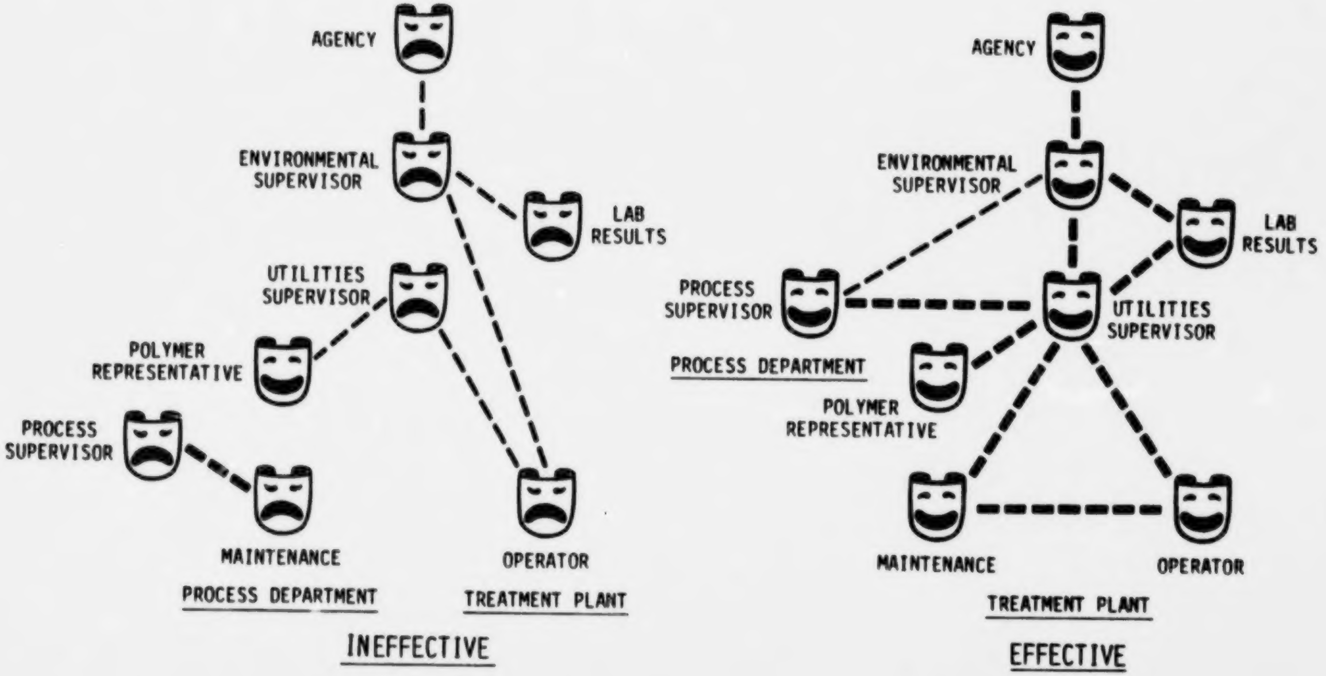

AGENCY
ENVIRONMENTAL SUPERVISOR
LAB RESULTS
UTILITIES SUPERVISOR
POLYMER REPRESENTATIVE
PROCESS SUPERVISOR
MAINTENANCE
OPERATOR
PROCESS DEPARTMENT
TREATMENT PLANT
INEFFECTIVE
AGENCY
ENVIRONMENTAL SUPERVISOR
LAB RESULTS
PROCESS SUPERVISOR
UTILITIES SUPERVISOR
PROCESS DEPARTMENT
POLYMER REPRESENTATIVE
MAINTENANCE
OPERATOR
TREATMENT PLANT
EFFECTIVE

Figure 6-1. O&M communication structure.

The utilities supervisor also must maintain frequent and effective communication with the lab to be kept abreast of analytical results. These results are indicators of treatment system performance that can be communicated up or down the management ladder as required.

Good communication lines also should be established between the utilities supervisor and the environmental supervisor to keep the latter informed regarding how well the plant's treatment systems are operating and whether problems have arisen that have caused or could cause outfall excursions. The environmental supervisor must also have an open line to the lab supervisor and to the utilities supervisor. The latter needs to know how treatment system problems can affect an outfall, how the regulatory agencies may react to certain situations, and what new regulatory developments are occurring that will affect him or her.

Another important communication line is that between the utilities supervisor (or his operators) and the process supervisor (or his operators) so that process problems or significant changes affecting water quality and quantity can be relayed to the treatment system operating department as quickly as possible. Intermediate action often can be taken at the treatment plant to reduce the possibility of a treatment system upset (e.g., diversion of spilled material or sludge to a holding basin).

Ineffective communication, as shown in the left portion of Figure 6-1, was much less evident at the visited plants. Where it was a problem, however, things did not go as well. As the figure shows, because no one person is the key person, everyone acts in an independent, haphazard manner. The environmental contact bypasses the utilities supervisor to give the lab information. (This system did work at one plant, but that was because the operator was highly trained and very dependable. In this case, the operator would then relay important information from the environmental department to his supervisor.) At several of the plants visited, there was essentially no communication between process people who operated scale pits and ammonia stills and the utilities personnel responsible for the operation of subsequent treatment equipment. This missing communication link can work for a while if the utilities people closely monitor the water coming into their systems and can react quickly to changes (because of their own experience or by having diversion tanks available). This backward method of operation often leads to problems when a process upset occurs, and it is too late for the treatment operator to do anything about it. Conversion from an ineffective to an effective communication structure is very cost-effective; the same personnel are involved and no new equipment is required.

6.2 OPERATOR TRAINING

The proper training of operators is necessary for effective operation of a wastewater treatment system. The operators need to know:

- How their systems operate and how to handle routine daily problems.
- What pollutants are being removed and where they are destined to go (sinter plant, landfill, recycle).
- Where the treated water goes.
- How the steel mill depends on them (directly for return of needed water, or indirectly through potential regulatory action).
- What daily routines must be followed.
- What to do during emergency situations.

An effective operational practice at one plant was a personalized examination prepared by the operating supervisor and given to the operators. Although this test was not required by the plant or given by other operating supervisors within the plant, one interviewed supervisor was convinced that it was necessary for his own assurance that the operators knew how to handle all conceivable situations.

Talking to various operators revealed that those who were present at system startup and had the benefit of receiving thorough training by the equipment manufacturers were better trained than subsequent generations of operators who received less formalized training or practically none at all.

An effective operational practice, therefore, is to ensure that new operators receive the same level of training as the "startup" operators. If this is not possible, one effective practice is to have a process supervisor (for the process whose wastewater is going to treatment) show the operators the source(s) of wastewater and explain the process variations that can affect the flow rate and the quality of the wastewater. Also, a representative of the plant's environmental department should explain the importance of effective operation and the role of the environmental department.

Another useful aid that some operators had developed involved simplified schematics of their equipment and/or overall treatment scheme. These diagrams were usually much less complex than those in the O&M manuals provided by the design engineers.

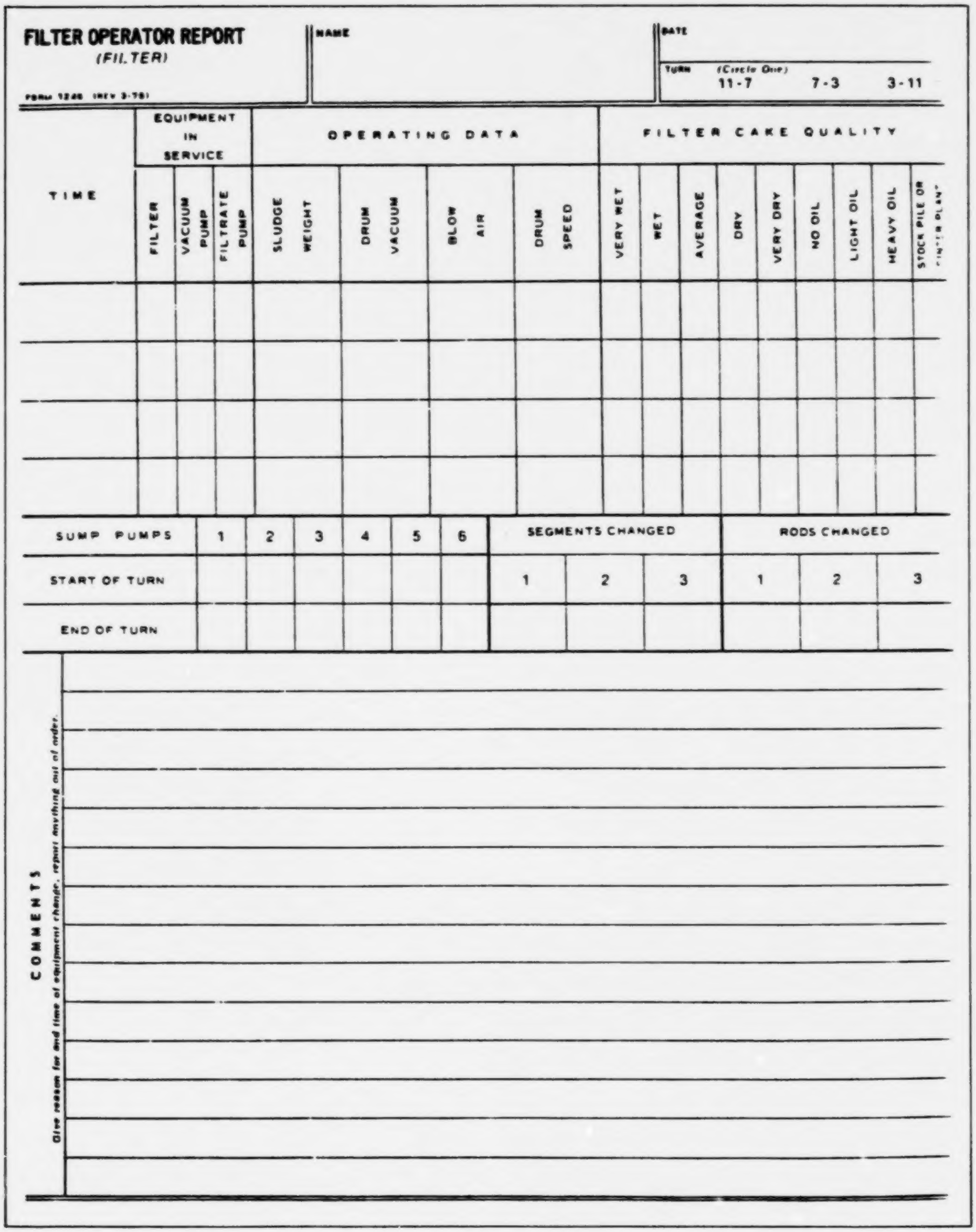
6.3 LOGS/RECORDKEEPING

Good logs and recordkeeping are effective O&M tools. The plant visits indicated that current practice varies from maintaining essentially no records to recording numerous parameters every two hours. It would be difficult, if not impossible, to recommend a standard record sheet and logging frequency for a particular treatment system because operations vary greatly from plant to plant and system to system. The variables depend on management philosophy, who benefits from the logs, the need for the recorded data, the degree of instrumentation for a given system, etc.

Nevertheless, it was noted that the operators at those plants that had well-operated systems made a practice of logging in key operating parameters on a periodic basis. In addition, the operating supervisors at these plants regularly review the logs for abnormal conditions and initiate followup action. In other words, the logs were meant to be used. Examples of effectively used log sheets (blanks) at two plants are shown in Figures 6-2 and 6-3.

Collected data also are useful for plotting certain parameters versus time in order to show trends. This can indicate how process changes affect water quality of the influent to a control system, how control system changes or a new polymer affects outlet water quality, or how a new equipment installation affects outfall water quality. It is frustrating to have to search through reams of logs and records (Figure 6-4) to try to understand what effect a change had on something.

The use of records to plot trends did not appear to be a common practice at any of the plants visited; however, such plots can be effective in



FILTER OPERATOR REPORT
(FILTER)

FORM 1246 (REV 3-78)

NAME

DATE

TURN (Circle One) 11-7 7-3 3-11

TIME	EQUIPMENT IN SERVICE			OPERATING DATA				FILTER CAKE QUALITY								
	FILTER	VACUUM PUMP	FILTRATE PUMP	SLUDGE WEIGHT	DRUM VACUUM	BLOW AIR	DRUM SPEED	VERY WET	WET	AVERAGE	DRY	VERY DRY	NO OIL	LIGHT OIL	HEAVY OIL	STOCK PILE OR SINTER PLANT

SUMP PUMPS	1	2	3	4	5	6	SEGMENTS CHANGED			RODS CHANGED		
START OF TURN							1	2	3	1	2	3
END OF TURN												

COMMENTS

Give reason for and time of equipment change, report anything out of order.

Figure 6-2. Example of log sheet - vacuum filter.

WASTE LIQUOR ANALYSIS

MONTH

YEAR

DATE	BIOLOGICAL OXIDATION PLANT																							
	FEED LIQUOR					AERATION TANKS										CLARIFIER OVERFLOW								
						SUSPENDED SOLIDS PPM				SET. TEST %	SVI	VOLATILES WEIGHT %												
	pH	NH_3 (ppm)	Phenol (ppm)	Thio-Cyan (ppm)	S.S. (ppm)	SW	SE	NW	NE			SW	SE	NW	NE	pH	NH_3 (ppm)	Phenol (ppm)	Thio-Cyan. (ppm)	S.S. (ppm)	Phosphate (ppm)	Volatiles Weight (%)	S.R.T (Days)	COMMENTS
1																								
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3																								
4																								
5																								
6																								
7																								
8																								
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Figure 6-3. Example log sheet - biological treatment system.

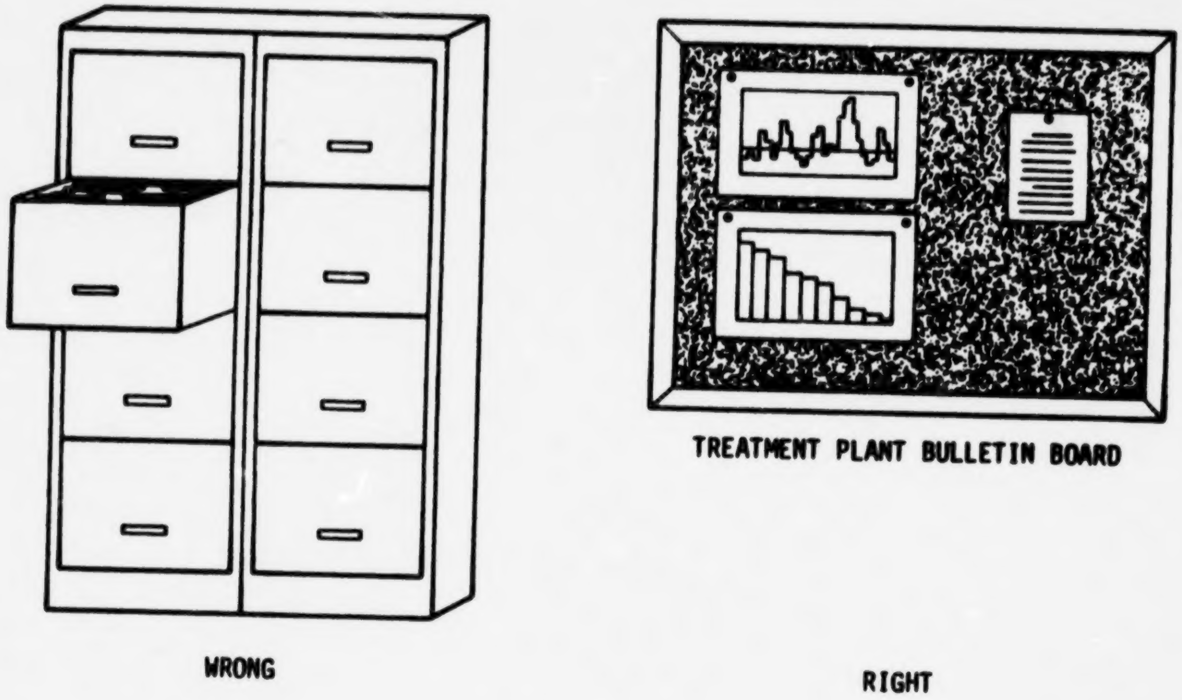
TREATMENT PLANT BULLETIN BOARD
WRONG
RIGHT

Figure 6-4. Effective use of records.

illustrating a point to process, utilities, and environmental supervisors and to regulatory agency personnel.

A process supervisor at one plant was able to use data that he had plotted to convince plant management there would be fewer permit excursions and less process equipment downtime if a preventive maintenance (PM) schedule were followed. Figure 6-5 shows a section of the plotted data. For each peak (excursion above control limit), the process supervisor reviewed maintenance work orders and was able to write down the cause of the excursion. In doing this over an approximate two-year period, he saw a trend in equipment breakdowns or pluggages vs. the excursions. This information enabled him to prepare a preventive maintenance schedule (Figure 6-6), which was implemented by management and has proved to be very effective.

Most plants have log sheets they have developed for their systems. Although none was noted in the plants visited, another effective tool that the authors have seen in use outside the iron and steel industry is the inclusion of a control chart with maximum and/or minimum parameter values shown on the log sheet so the operator can circle exceeded values. This forces the operator to know what the acceptable operating range is; it also provides his supervisor a quick visual aid for ascertaining where deviations from the normal range have occurred. By taking this a step further, a deviation or exception report can be prepared periodically (e.g., weekly or monthly) to show the supervisor how the system has been operating.

6.4 STAFFING

Obviously, proper operation of a treatment system requires a sufficient number of operators (and assistants and helpers) with clearly defined job functions.

The systems at all the plants visited during this study were well staffed. At one plant, however, an efficient operator had to devote all of his time to manually controlling the treatment system (filtration plant). Had this operator been responsible for areas other than the filtration plant, the filters would have plugged and the system would have been damaged and/or solids in the filter effluent would have increased dramatically.

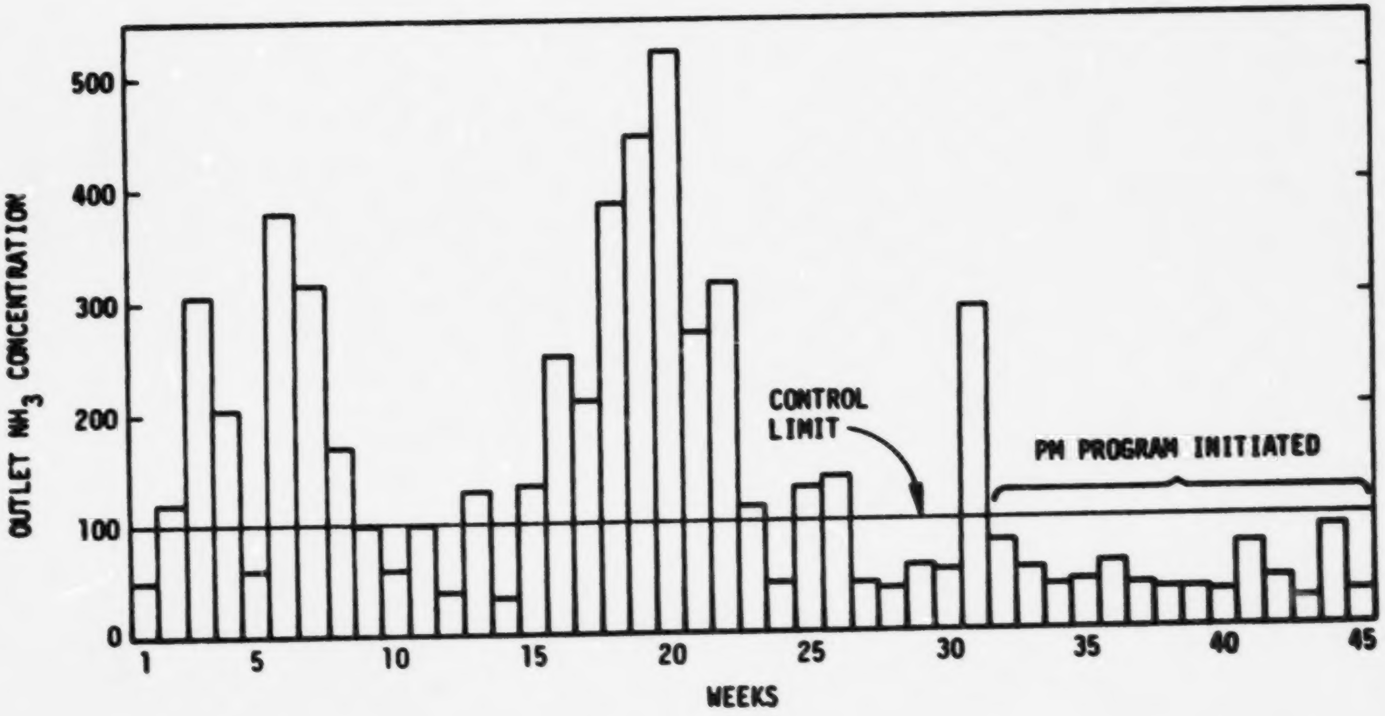

Figure 6-5. Ammonia still performance.

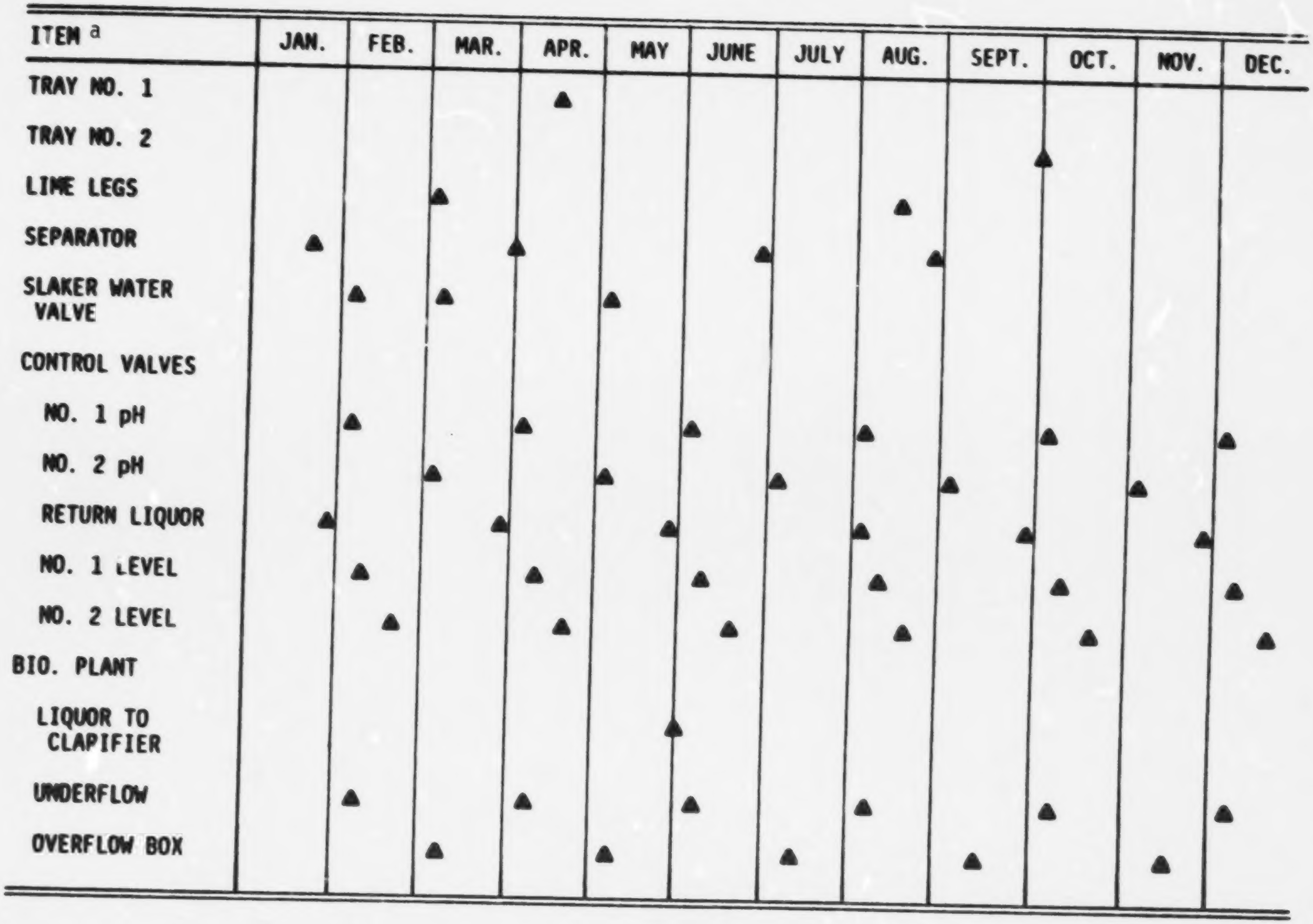

Figure 6-6. Example of annual preventive maintenance schedule.

[a] The dates shown represent the times when the equipment items are inspected and usually thoroughly cleaned.

One final word on staffing (somewhat reiterating earlier discussions) has to do with the importance of personnel selection to the operation of water pollution control systems. Usually, personnel with adequate seniority can bid for an opening in the utilities department regardless of what their prior mill experience has been. One operator at a hot strip mill treatment system (who had been working as a hot strip process operator for years) recently bid into his new position. An assistant operator at another plant had bid from the maintenance department into a central treatment plant position. Job bidding has been fairly intense at some plants recently because the current economic situation has forced plants to lay off many of their personnel. The point is that it is important to try to select job bidders at least in part on their qualifications and interest in operating pollution control equipment. The assistant operator (from a union plant) mentioned he was given a qualifying test before being accepted into the utilities pollution control department. Although the test was not written specifically for operation of the central treatment plant equipment, passing it did require general knowledge of related equipment, such as pH control, pumps, analyzers, and control board operation.

Plant management should be atuned to the needs of the utilities department in making appropriate job replacements. If possible, environmental and utilities department managers should exert their influence in the personnel selection.

6.5 TREATMENT SYSTEM AUDITING

Results of this study indicate that most plants have proceeded from permit negotiation to system design to routine operation without ever having stepped back to take an overview of their situation. As in any ongoing operation, the individuals involved are too busy with day-to-day concerns to take time to assess their overall system. One person is aware of one set of the problems and another person is aware of a different set, but they seldom have the opportunity to exchange notes. A formal O&M audit had not been performed in any of the plants visited, and none was planned. One company (not visited) is currently performing such a study on their own, however.

It is suggested that audits or self-evaluation programs be implemented periodically (e.g., annually) by a plant team or an outside consultant. When the evaluations reveal less-than-optimum conditions, corrective action should be taken with followup to ensure that approved suggestions have been carried out.

SECTION 7

SUMMARY OF PERMIT EXCURSION DATA

At the onset of the project, an intensive effort was aimed at contacting and, in some instances, visiting state offices to obtain pertinent wastewater monitoring information for steel mills.

To obtain or renew a permit to discharge any water into a receiving stream, plants must submit a National Pollutant Discharge Elimination System (NPDES) permit application to EPA or to the state in which the plant is located. (Most states have received authority from EPA to administer the NPDES program and issue permits to plants.) The permit applications contain information such as the number of effluent discharge points (outfalls), operations that contribute water to the outfalls, average flows, wastewater treatment descriptions, intake and effluent pollutant characteristics, and process production rates. In current consolidated permit applications, the pollutant characterization must include at least one analysis for each of the 129 organic toxic pollutants (except pesticides) and any of 36 conventional and nonorganic pollutants expected to be present in a discharge. Oftentimes, the plants will also submit water flow diagrams showing outfall locations to correspond with the descriptions.

After a permit application has been submitted, the state and plant resolve any data uncertainties and negotiate monitoring requirements before a permit is eventually written for the plant. The permit specifies limitations for each outfall based on the processes that discharge to the outfall and the maximum production rates achieved in the preceding five years. An outfall is often defined as a sampling point at the discharge of a treatment system. The permit also requires that the outfalls be sampled by the plant on a specific frequency (e.g., twice a week, daily, continuously). The sample (continuous or grab, as specified) must be analyzed for the permitted pollutants, and a monthly report must be issued to the state noting excursions of any permitted limits. An explanation of the cause of the exceedances and an explanation of corrective action that has been or will be taken are also required. The state then submits quarterly noncompliance reports on the plant to the EPA regional office.

Information in the state files (i.e., permit applications, permits, monthly reports) and submitted by the states, such as quarterly reports and inspection reports, was obtained during this project. The primary reason for obtaining the noncompliance (exception) reports was to review and categorize the causes of the problems and the corrective actions taken and then to evaluate their relationship to operating and maintenance practices. (The collected noncompliance data include excursions for all processes at a steel mill, not just the five described in this report.)

The extent of the information gathering included 35 integrated steel mills in 12 states (Alabama, California, Colorado, Illinois, Indiana, Kentucky, Maryland, Michigan, Ohio, New York, Pennsylvania, and West Virginia). On the average, the noncompliance data obtained on each plant covered a 24-month period.

It is worth noting that the plants freely report deviations from permit conditions, even though, in many cases, they were either unable to determine or simply failed to report the cause of the excursion.

7.1 FREQUENCY AND RANKING OF PROBLEMS CAUSING PERMIT NONCOMPLIANCE

In an attempt to understand and categorize causes of problems and corrective actions reported by the 35 plants, a form was developed to summarize information from the noncompliance reports (NCR's). Examples of completed forms for three unidentified plants are shown in Tables 7-1 through 7-3. After all of the data were summarized onto the forms, the causes of the reported excursions were numbered and similar causes were assigned the same number. The approximately 30 categories identified this way are shown in Table 7-4. (The number of excursions, by pollutant, was also determined from the data on the forms. This information is graphically illustrated in Figure 7-1.)

TABLE 7-1. EXAMPLES OF WASTEWATER NONCOMPLIANCE INCIDENTS AT STEEL MILLS - PLANT 1

Date of incident	Outfall	Parameter	Unit of measure	Actual	Allowable limit	Cause of Problem	Corrective action
4/22/81	"B"	O&G	kg/day	2,110	919	During cleanup of Lagoon No. 3, total flow of Tin Mill wastewater was diverted to Lagoon No. 4, which caused temporary disruption to settled solids.	Temporary problem that occurred only during cleanout of No. 3 Lagoon.
4/23/81	Same	O&G	kg/day	2,163	919		
4/24/81	Same	O&G	kg/day	1,299	919		
4/22/81	Same	SS	kg/day	6,236	4,137	(Same as above.)	(Same as above.)
4/23/81	Same	SS	kg/day	23,941	4,137		
4/24/81	Same	SS	kg/day	30,774	4,137		
4/25/81	Same	SS	kg/day	16,554	4,137		
4/25/81	"A"	-		-	-	Bypass. Blast furnace wastewaters were discharged to "A" Outfall Lagoon. Valve failure on South Thickener.	Valve was repaired and bypass was discontinued.
4/28/81	"B"	Tin	kg/day	680	486	Leaking pump was used in waste sludge transfer from Tin Mill.	Pump was repaired.
4/29/81	Same	Tin	kg/day	749	486		
5/12/81	Same	O&G	kg/day	1,228	919	One of two lagoons comprising the outfall was being cleaned, and total flow was diverted to the other.	After cleaning the pertinent lagoon and resuming operation of both, compliance was achieved.
5/13/81	Same	O&G	kg/day	3,546	919		
5/19/81	Same	O&G	kg/day	1,638	919	One of two lagoons was being cleaned (North Lagoon); higher than normal solids loading to intake due to heavy rains.	(Same as above.)
5/20/81	Same	O&G	kg/day	2,009	919		
5/21/81	Same	O&G	kg/day	1,909	919		
5/22/81	Same	O&G	kg/day	1,305	919		
5/23/81	Same	O&G	kg/day	1,445	919		
5/20/81	"P"	Total CN	kg/day	95.8	53.9	Steam loss at crude liquor still due to drop in temperature.	Temperature returned to normal.
5/15/81	HSM-Blooming Mill WTP	-		-	-	Bypass. WTP was shut down because of failure of three of four settling basin scale drag-out conveyors. Excessive solids buildup caused drive shear pins to fail.	Excess solids were removed and high-strength shear pins were installed.

TABLE 7-2. EXAMPLES OF WASTEWATER NONCOMPLIANCE INCIDENTS AT STEEL MILLS - PLANT 4

Date of incident	Outfall	Parameter	Unit of measure	Actual	Allowable limit	Cause of Problem	Corrective action
2/12/81	6 or 039	O&G	mg/liter	12.0		Maintenance problem on 84-in. Hot Strip Mill horizontal scale breaker oil and hydraulically overloaded Roughing Mill scale pit.	Corrected problem and performed subsequent sampling; was in compliance.
4/5/81	17 or 034	Zn	mg/liter	0.7		Interruption in lime feed to mixing tank at Zinc Pretreatment Facility.	Lime feed was restored. Performed subsequent sampling; was in compliance.
4/14/81	6 or 039	O&G	mg/liter	11.3		Nonrepresentative sample due to rainfall.	Performed subsequent sampling; was in compliance.
5/3/81	17 or 034	O&G	mg/liter	21.0		Break in force main between "N" wastewater pump station and Terminal Treatment Plant.	Repaired break in line. Repairs took 48 hours. Performed subsequent sampling; was in compliance.
5/26/81	2 or 007	pH		2.2		Coke plant gas processing area. Leak in sulfuric acid storage tank.	Tank taken out of service for repairs on 5/27/81. Performed subsequent sampling; was in compliance.
6/18/81	17 or 034	Sn	mg/liter	2.4		Stainless Annealing and Pickling Line. Level control problem in No. 3 Pickling Tank resulted in loss of acid to process wastewater system.	Necessary action was taken to eliminate discharge.
6/22/81	6 or 039	O&G	mg/liter	15.0		Lubrication line on a roughing mill stand ruptured. Discharge hydraulically overloaded scale pit.	Problem was corrected the same day.
8/12/81 8/12/81	17 or 034 17 or 034	O&G Cr	mg/liter mg/liter	17.1 0.32		One terminal treatment plant flocculator-clarifier was removed from service for required maintenance. This and high flow resulted in hydraulic overloading of the plant.	Maintenance was completed same day and normal operations were resumed. Performed subsequent sampling; was in compliance.
9/28/81	6 or 039	O&G	mg/liter	14.6		Broken seal on vertical scale-breaker in Roughing Mill. Caused scale pit to be hydraulically overloaded.	Problem was corrected same day as problem discovered. Performed subsequent sampling; was in compliance.

TABLE 7-3. EXAMPLES OF WASTEWATER NONCOMPLIANCE INCIDENTS AT STEEL MILLS - PLANT 29

Date of incident	Outfall	Parameter	Unit of measure	Actual	Allowable limit	Cause of Problem	Corrective action
12/3-4/81	020	Phenol	mg/liter	4.5		Cause unknown.	None specified.
12/81	020	Phenol	mg/liter	0.34 0.21 0.21		Cause unknown.	None specified.
12/81	021	pH	SU		6.0	Two of 33 measurements taken were in violation.	None specified.
12/81	021	Phenol			0	Zero limitation for phenol not met, but reduced levels were recorded.	None specified.
1/82	020	TSS	lb/day (avg.)	9,696	9,147	Extreme cold weather, high winds, ruptured pipelines, frozen process instrumentation.	None specified.
1/82	020	Phenol	mg/liter (max.)				
1/82	020	Phenol	mg/liter (avg.)				
1/82	220	Phenol	mg/liter (max.)			(Same as above.)	None specified.
1/82	220	Phenol	mg/liter (avg.)				
1/82	021	pH	SU		6.0	Two of 27 measurements made were lower than allowed limitation.	None specified.
2/1/82	020	Phenol	mg/liter (max.)	40		Storage tank capacity met, therefore weak ammonia liquor discharged to river.	None specified.
2/1/82	020	Ammonia	mg/liter (max.)	79			
2/82	020	Ammonia	mg/liter (avg.)			Free ammonia still drain line was plugged, a bottom seal leaked, and steam condensate pump motor reversed.	All adjustments were properly made.
2/82	020	Ammonia	mg/liter (max.)				
2/82	220	Ammonia	mg/liter (avg.)			(Same as above.)	(Same as above.)
2/82	220	Ammonia	mg/liter (max.)				

TABLE 7-4. SUMMARY OF THE CAUSES OF REPORTED EXCURSIONS

Reported causes of violations	Reported noncompliance incidents			No. of plants reporting cause	Percentage of plants
	Total No.	Percentage of total	Adjusted percentage[a]		
1. Equipment failure	5	0.3	0.7	3	9
2. Equipment/line plugging	21	1.4	3.1	7	20
3. Cause undetermined - still investigating	91	6.1	-	13	37
4. Operator, maintenance, or procedural error	59	4.0	8.6	20	57
5. pH probe malfunction, breakage, not calibrated	24	1.6	3.5	8	23
6. Process startup	6	0.4	0.9	4	11
7. Pump malfunction	15	1.0	2.2	8	23
8. Equipment down for maintenance	6	0.4	0.9	4	11
9. Equipment operational problems, equipment malfunction	14	0.9	2.1	6	17
10. Leaks, spills, tank overflows, line breakages, chemical cleaners leaking into wastewater	84	5.6	12.2	17	49
11. High solids content and other pollutants in plant intake water	33	2.2	4.8	8	23
12. Lime addition: excessive or lack of, plugging	9	0.6	1.3	2	6
13. No response given (no identification of cause, no further investigation mentioned)	672	45.0	-	26	74
14. Response given but cause not defined	20	1.3	-	9	26
15. Heavy solids caused by lagoon, settling basin, scale pit cleanout	27	1.8	3.9	9	26
16. Valve malfunction or failure	5	0.3	0.7	1	3
17. Level indicator/metering device malfunctioned or damaged	10	0.7	1.5	7	20
18. Chemical additive problem (lack of supply, testing new additive)	13	0.9	1.9	7	20
19. Lab sample handling/analytical error	12	0.8	1.7	4	11
20. Cold weather problems (frozen lines and/or equipment)	21	1.4	3.1	13	37
21. Low flow conditions	16	1.1	2.3	4	11
22. Power/electrical failure	9	0.6	1.3	7	20
23. Nonrepresentative sampling, random sampling variance	43	2.9	6.3	6	17
24. Storm water runoff	33	2.2	4.8	9	26
25. System imbalance/hydraulic overload	44	2.9	6.4	4	11
26. New coke source (high in ammonia)	96	6.4	14.0	2	6
27. Treatment system startup problems	22	1.5	3.2	1	3
28. Other weather conditions (wind, rain stirring up solids)	31	2.1	4.5	6	17
29. Process problems	21	1.4	3.1	8	23
30. Working with agency (phases of negotiating, designing, or installing equipment to eliminate cause)	23	1.5	-	3	9
31. Low production problems	7	0.5	1.0	1	3
Total	1492	~100	100		

[a] Excludes reports showing undetermined cause (Nos. 3, 13, 14) and working with agency. Total equals 686.

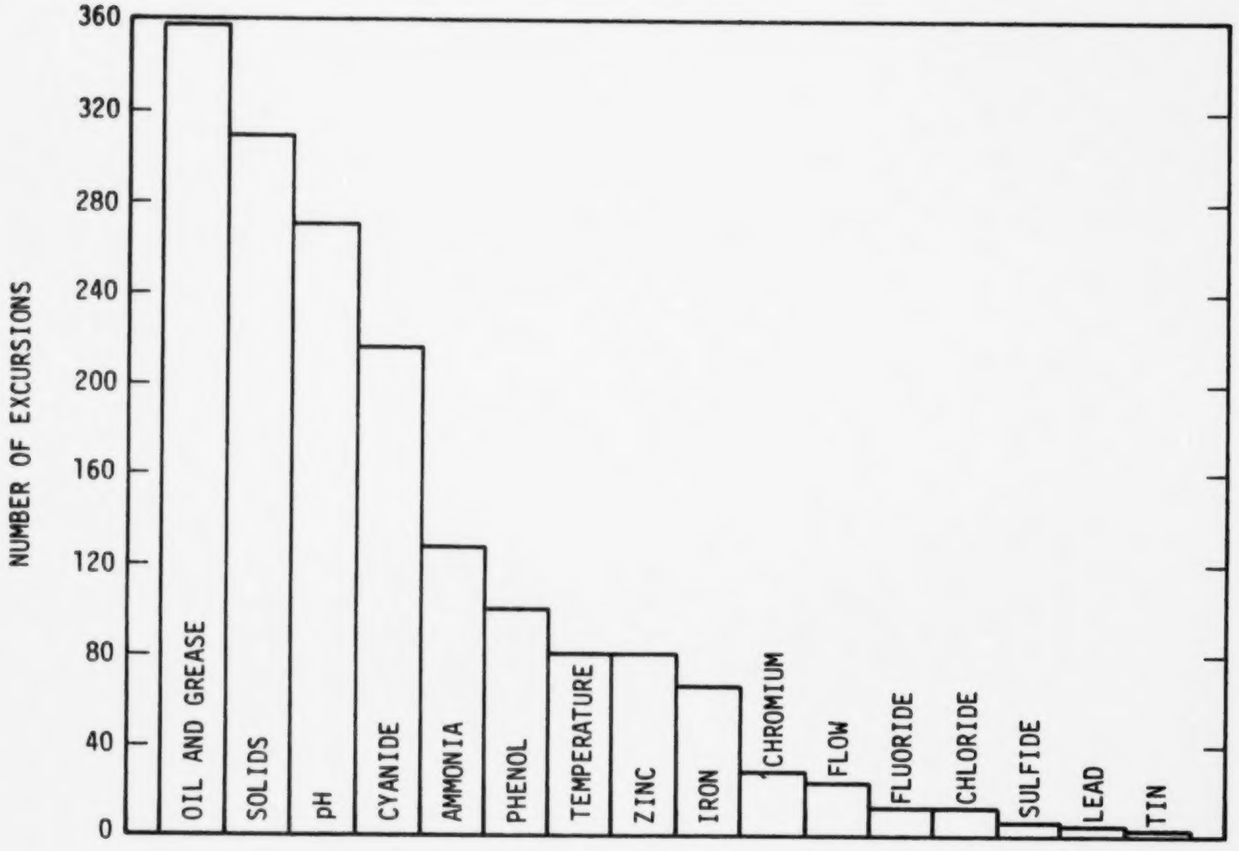

Figure 7-1. Number of excursions, by pollutant, based on self-monitoring data.

Table 7-4 illustrates a number of points. First, under the column "Reported Noncompliance Incidents," by far the greatest number of letters from the plants (i.e., 45 percent) do not give a response as to the cause for the incident nor imply that they will find one. Another 6 percent of the responses say the cause is undetermined, but they are still investigating. Another smaller percentage of letters gave a response but do not really indicate the cause. Since the widely used "cause unknown" response is not helpful in the study, an "adjusted percent" column is shown in Table 7-4.

Because of their similarities, some kinds of causes can be grouped for further evaluation. For example, weather-related problems reported by the plants include high solids in plant intake water due to heavy rains affecting the lake or river solids, freezing conditions (e.g., pipes, samplers, equipment), storm water runoff (causing agitation of solids in lagoons, basins, etc.), and other weather conditions such as wind (e.g., affecting oil skimming). These similar causes are grouped into categories, as shown in Table 7-5. The percentage of reported causes is also shown. This is calculated by summing the percentages of the individual numbered causes (from Table 7-4) shown in parentheses. Some specific examples of reported process problems are ineffective wringer rolls on the pickle line (causing high acid content rinse water discharges), excessive lime carryover in the BOF grit system, problems with column agitator drive in the dephenolization plant, and loss of steam in the ammonia still (causing high-ammonia content still bottoms).

Some other categories listed in Table 7-5 show causes for water excursions, but their importance as a cause receives less emphasis in this discussion because these categories either are not reported frequently (e.g., line plugging and power failures) or the percentage of plants reporting the cause is low (e.g., system imbalance/hydraulic overload, chemical additive deficiency).

The percentage of plants reporting a cause represents a summation of plants reporting the individual causes shown in each category, excluding double counting of plants that reported more than one cause in a category.

Table 7-5 clearly illustrates the several main categorical reasons for water excursions. By weighing evenly the percentage of reported causes and percentage of plants reporting the causes, one finds the relevant causes are:

TABLE 7-5. SUMMARY OF GROUPED CAUSES

Further grouping of reported causes of violations	Percentage of reported cause	Percentage of plants reporting cause
Process/treatment system equipment failures and malfunctions (incl. 1, 6, 7, 8, 9, 12, 27)	11.2	46
Equipment/line plugging	3.1	20
Instrumentation failures and malfunctions (incl. 5, 16, 17)	5.7	37
Operator error, maintenance error or procedure	8.6	57
Leaks, spills, tank cverflows, line breakages	12.2	49
Weather-related problems (incl. 11, 20, 24, 28)	17.2	60
Solids caused by lagoon, settling basin, or scale pit cleanout	3.9	26
Chemical additive deficiencies/testing	1.9	20
Nonrepresentative sampling (incl. 19, 23)	8.0	29
System imbalance/hydraulic overload	6.4	11
New coke source	14.0	6
Process problems (incl. 21, 29, 31)	6.4	37
Power/electrical failure	1.3	20
	≅100	

- Weather-related problems
- Leaks, spills, tank overflows, line breakages
- Process/treatment system equipment failures and malfunctions
- Operator error, maintenance error or procedure
- Nonrepresentative sampling
- Process problems
- Instrumentation failures and malfunctions

Most of these categories are self-explanatory. The "process problems" category, however, is somewhat nebulous and probably includes many things that could be put in the process equipment malfunctions category, although some of the process problem reasons given in the noncompliance reports are not clear.

Another category that is given less emphasis is the "new coke source," which resulted in numerous ammonia violations. This appears to be a valid cause; however, because it was given by only two plants, it is not considered to be representative of reasons reported by the iron and steel industry.

Noncompliance data can be used and presented in a number of ways to provide interesting results; however, the methodology described and the main categories of causes were selected in an attempt to show the primary problems the industry faces that result in noncompliance and how these problems relate to O&M practices.

The following subsections present brief discussions of several selected categories and how they relate to O&M.

7.1.1 Weather-Related Problems

Adverse weather can be difficult to deal with--impossible, if weather conditions are extreme, as in the case of flooding. The use of normally effective O&M practices has little effect on many of these problems. Some O&M practices can help, however; e.g., winterizing efforts made by plants before cold weather arrives. One plant visited used an extensive winterizing checklist every year. This list included testing of heat tracing, installing new tracing and insulation, and more thorough testing of spare equipment that had not been operated much. Emphasis in winterizing efforts appeared to differ depending on how far north the plant was located. Some plants insulated all major piping subject to freezing conditions, especially the important chemical additive lines such as those for phosphoric acid and polymer systems. Some plants made considerable effort to house important equipment such as filtering systems, instruments, and meters.

In summary, some O&M practices can be implemented to reduce weather effects, but their use is limited depending on the severity of the weather.

7.1.2 Leaks, Spills, Tank Overflows, Line Breakages

Seemingly, effective operating and maintenance practices could minimize many of these frequently reported causes. For example, tank overflows usually can be prevented by having operators make periodic checks of tank levels or by having operators or maintenance personnel perform preventive maintenance checks of level-indicating equipment. Controlling spills is another matter. Some degree of spill prevention and countermeasures control (SPCC) should be practiced at all plants to prevent spills from occurring or, if they do occur, from getting into sewers (and, of course, to minimize worker risk if the spill contains dangerous/hazardous material). Implementation of an effective SPCC plan is a management decision. Such a plan is required under the Resource Conservation and Recovery Act (RCRA), which regulates the control of hazardous waste. This plan can be extended to cover leaks, spills, tank overflows, and line breakages. Such a plan may necessitate the construction of new equipment, diking, etc., or a careful evaluation of how to utilize existing equipment [e.g., pumping of spills back to the source or to an emergency tank (perhaps obtained from the salvage yard)].

Among the numerous causes for leaks and line breakages are the very corrosive nature of the material, operator error resulting in pressure rises in the equipment that burst a line, and old equipment/lines. Operator training or preventive maintenance can help to avoid some of these problems. No evidence was found that ultrasonic or other testing of pipe condition is practiced.

7.1.3 Equipment Failures and Malfunctions in Process/Treatment Systems

With regard to the reasons for failure or malfunctioning of equipment, the reported causes of noncompliance incidents often do not provide this level of detail. Therefore, the situation is difficult to evaluate. As in the case of broken lines, equipment failure can result from overload, operator error, lack of preventive maintenance, age, freezing conditions, etc. At least a portion of the time, effective O&M practices can prevent equipment failures and malfunctions.

7.1.4 Operator Error, Maintenance Error, or Maintenance Procedure

Incidents of noncompliance caused by operator or maintenance errors or by maintenance procedures can be minimized by effective O&M practices. Proper and adequate personnel training can be implemented, or if already practiced, periodic review of this training can be effective. If the errors appear to be made most frequently by one person, supervisors should work with that person. Everyone makes errors, but frequent occurrences indicate that management needs to place more emphasis on the workers' careful attention to proper operating and maintenance procedures.

At times, a standard maintenance procedure will result in an eventual violation. For example, a vessel may have to be drained before it is fixed. If the liquid goes into a sump that ultimately ties into a treatment system, an excursion could result if the drained liquid is too concentrated or if it is incompatible with the treatment system. This is not a maintenance error, as the procedure calls for draining the tank to the sump. The person responsible for draining the vessel may have no idea where the sump drains to. It is management's responsibility to evaluate the situation and set up an alternative procedure.

7.1.5 Nonrepresentative Sampling

There can be two reasons for this. First, the person taking the sample did not take a "representative" sample. The EPA has spelled out procedures for taking representative samples, using proper sampling techniques, and protecting the samples until they are analyzed. A new publication, entitled "Handbook for Sampling and Sample Preservation of Water and Wastewater" (EPA 600/4-82-029), is available. All personnel involved with taking samples should be properly informed of and understand the procedures. Second, the representative sampling procedure may have been followed properly, but the container of wastewater taken from the sampling point may not be "representative" of the wastewater at that point. This can be true of grab samples. Following the proper procedure and observing the water during sampling can help decrease the chance of getting a "bad" sample. When possible, a series of grabs should be taken for compositing or a composite sampler should be used if there is doubt about a sample.

7.1.6 Process Problems

Causes of these problems are not usually clearly defined or reported at all in the NCR's. For example, "Problem with the ammonia still was responsible for the excursion," tells the reader where the source of the problem was, but not the cause. Despite effective O&M practices (e.g., periodic operator and maintenance inspections of equipment, keeping tabs on influent and effluent key parameters, operator training), process upsets can occur; however, they should be more clearly defined.

7.1.7 Instrumentation Failures and Malfunctions

Effective O&M practices can reduce failures and malfunctions of instrumentation. However, instruments are sensitive and they are not infallible. Wastewater from steel mill processes containing solids, oils, acids, bases, and other pollutants inherently causes periodic instrumentation problems. The most effective O&M practices for minimizing the effects of instrument problems are operators' practices that back up the instruments. These have been discussed throughout the report, but examples of operator backup practices are periodic sampling to test for pH, ammonia, and turbidity; inspecting pumps, flumes, pipe discharges to see if flow appears normal; or observing flow of polymer into a clarifier. People cannot replace instruments, but good operating practices can often quickly discover an instrument problem, and a good operator can manually control and monitor the system more closely until the instruments are back on line.

In summary, observation and the application of a statistical approach to the review of noncompliance reports covering an average of two years each for 35 major steel mills indicate that the seven primary categories of causes of upsets (not including responses that say "cause undetermined") are closely related to operating and maintenance practices. It is believed that effective (and cost-effective) practices can help somewhat to reduce excursions falling into all of these categories, and should help considerably in those categories where the causes are directly related to O&M (e.g., operator and maintenance errors, certain tank overflows, and certain nonrepresentative sampling). These observations are intended to demonstrate the value of implementing or increasing effective O&M practices in their efforts to eliminate many causes for water excursions in the iron and steel industry.

Most of the systems of the plants visited in this study are well operated and maintained, and they implement the effective O&M practices described in Sections 3 and 4. That these plants have reported few excursions in the past two years can be attributed to their management and operating and maintenance staff, and further emphasizes the effectiveness of these practices.

7.2 EFFECTIVE O&M PRACTICES TO ELIMINATE PROBLEMS OR REDUCE THEIR EFFECT

This subsection illustrates certain corrective actions that steel mills have taken in an effort to correct recurring problems that result in permit excursions. The corrective actions summarized in Table 7-6 were selected from the completed forms discussed earlier (examples of which are shown in Tables 7-1 through 7-3). These corrective actions are chosen because they are representative of effective O&M (or management) practices. The table shows the parameter violated, the cause of the problem, and corrective actions.

Examination of the information in Table 7-6 shows that the corrective actions can be grouped into effective O&M practice categories. These are shown below with explanations as required.

- Institution of regular inspections and monitoring.
- Operational procedures/instructions periodically re-emphasized to operators.
- Instruction of all plant and contract personnel of the importance of preventing or minimizing discharges (e.g., spills, cleaning fluids) to sewers. This practice also includes instructions to personnel of where sumps and sewers discharge, and if a spill occurs, what prompt cleanup/disposal procedures should be implemented.
- Development of new operating plans/procedures. These are developed when plants discover that their current plans are not adequate to prevent or minimize permit excursions. Such plans include spill

TABLE 7-6. WASTEWATER NONCOMPLIANCE INCIDENTS AT STEEL MILLS SUMMARY OF EFFECTIVE O&M PRACTICES

Parameter	Cause of problem	Corrective action
Phenol	Failure of caustic pumps on coke plant crude ammonia still.	Diversion to emergency lagoon.
CN	Loss of steam in cyanide stripper. Plugging problem in cyanide scrubber.	Spare scrubber utilized.
pH	Fouling of pH probe.	Preventive maintenance stepped up.
SS	Irregular manual operation of gravity filters in attempt to drain a pre-filter settling basin.	New draining procedures adopted.
pH	Due to draining of alkaline cleaner rinsings of tanks too quickly at continuous annealing facility.	Operational procedure will be re-emphasized.
O&G	Lagoon required skimming.	Problem was rectified and closer monitoring will be maintained.
O&G	Lagoon developed larger than normal oil build up, and removal operations had to be increased.	Problem was rectified and lagoon conditions will be monitored closely.
NH_3	Ammonia sulfate spillage from the coke plant byproducts was washed into sewer.	Standard operating procedures of loading and cleaning spillage are being reviewed by management.
pH	Manual operation of lime pumps rather than automatic because of broken pH probe.	A spare pH unit consisting of cables, probes, and sensors will be stored on location.
Oil	Employee opened valve to leaking pipe section	Valve was reclosed and a "Do Not Operate" sign was put up until repairs could be made.

(continued)

TABLE 7-6 (continued)

Parameter	Cause of problem	Corrective action
Oil	Broken tuyere oil injection pipe on blast furnace. This contaminated the blast furnace noncontact cooling water system.	Instituted regular inspections of the furnace tuyere oil injection system and installed metal shields to prevent oil from entering noncontact cooling water.
Cr	Leaks or overflows in tin free steel line (chromic acid used in electroplating process).	
	° Overflow of chromic acid operating tank.	Plant investigated level warning device.
	° Gasket leak in acid recirculating system.	Held meetings with operators and increased surveillance.
	° Pipe leak in chromic acid system.	
O&G	Nonrepresentative sample.	To correct sampling error will install sample pump with a suction line inserted into the sewer to provide a continuous sidestream flow.
Cr	Sink roll seal at No. 1 electrolytic tinning line failed. Chromic acid was released to sewer. Discharge would normally be treated by chrome treatment facility, but operator error occurred.	All operators at the facility have been re-instructed.
Cr	Gasket failed on a pipe flange.	Looking into the possibility of using conductivity alarm, thus allowing immediate control in future.
CN CN Fl	~10,000 gallons of waste plating solution was lost to the waste treatment system when the pipeline ruptured.	Will keep on hand extra chlorine at treatment plant for better handling of emergencies.
Fl	Operator error. Valve on mist eliminator was not closed.	Operator was disciplined.

(continued)

TABLE 7-6 (continued)

Parameter	Cause of problem	Corrective action
Cr	Boiler taken down every 2 years and acidified. Acid waste is neutralized and discharged, but this time it was too concentrated.	Either will discharge waste over longer period of time or dispose of it off premises.
Cr	Leaking seal on chrome tank.	Monitor/alarm system will be installed.
O&G TSS	Employee error or malfunction of detection equipment.	Reprimands.
Cr	First time tank cleaning caused overload of Cr to treatment plant.	In the future, material will be hauled off site during cleaning.
Zn	Tank overflow.	Developing plan to identify and control potential mishaps.
Zn	Cold weather freezing in sump pump line. Violation occurred during thawing.	Sump pumps will be "locked out" and any contents will be analyzed before discharge.
Fe sulfate	Blockage in pickle line waste acid overflow line created overflow greater than what treatment could handle.	Blockage was removed. Implemented several new operating practices at pickle line: ° Routine monitoring of pickle tank. ° Routine checking of waste acid overflow line. ° Routine inspection of rinse tank wringer rolls. ° Routine sampling/analysis of rinse tank discharge.
Total Zn	Excessive leakage from recirculating solution plating pumps on electroplate zinc line caused abnormally high amount of plating solution to be discharged to treatment plant.	Continue repair program, keeping better maintenance of the pump packing to prevent recurrence.

(continued)

TABLE 7-6 (continued)

Parameter	Cause of problem	Corrective action
Total Zn	Pumps freezing at deaeration tanks.	Insulation and heat recycling have been improved at this system to prevent recurrence.
TSS	Surges in recycle system from operation startup and shutdown caused inconsistent loadings on treatment system.	Startup and shutdown procedures have been revised.
Total Zn	Flux tank drainage during maintenance.	Drains have been piped to spent acid sump to prevent recurrence.
TSS	Loss of a coagulant aid feed to the filter backwash line due to a chemical suppliers late delivery.	The air supply line has been repiped to include two air filters in parallel. Adjusted our chemical order point so as not to run out of coagulant.
Zn	Faulty pH probe.	Probe was replaced. Also changed method of testing pH measuring equipment.
Oil	Lance on tuyere plugged, pressure built up, and oil entered steam trap that discharges condensate to cooling water discharge system.	Steam trap discharges are routed away from cooling water discharge system.
TSS	Chemist error - new employee.	Better supervision of employee.
SS	Operator error.	Operator reinstructed in proper procedure.
SS	During construction an additional SS flow discharged via outfall.	Construction personnel instructed that only compatible flows with current discharge stream are permitted.
Oil	Personnel disposed small quantities of oil to sewer system.	Operating personnel were reinstructed that this is against company policy.

(continued)

TABLE 7-6 (continued)

Parameter	Cause of problem	Corrective action
SS	Sometimes plant personnel and outside contractors use plant sewer to dispose of materials.	Memo sent to plant personnel forbidding disposition to sewer.
Zinc	Operator error.	Redirected personnel. Requirement set for immediate spill cleanup.
SS	High winds at intake caused abnormal dust loading.	Chlorine contact tank covered. Wall constructed around final clarifier. Coal storage piles treated to minimize fugitive dust. Personnel reinstructed.
Oil	Oil leak in wash oil cooler system at coke battery byproducts plant.	Leak immediately stopped. Additional baffle plate placed in oil collection sump. Drain line from oil collection sump to be opened every turn and checked for proper drainage.
Oil	Oil sheen from outfalls.	Rearrange booms where they will absorb most oil.

prevention/cleanup, startup/shutdown procedures, equipment draining procedures.

- Utilization or installation of spares and other backup equipment (e.g., emergency lagoons). This is more equipment oriented than operator/maintenance personnel oriented. The point though is that the decision to install this equipment is an effective management practice. Use of the spares/backups is the responsibility of the operators, and the assurance that the equipment will function properly is the responsibility of the maintenance department.
- Elimination or rerouting of drains/overflow pipes. Because of the size and complexity of steel mill operations, it is not uncommon to have miscellaneous overflow drains and pipes with periodic discharges going to a wastewater treatment system. This situation is oftentimes the result of retrofitting wastewater equipment to an old plant whose sewer and piping blueprints have not been updated. If the periodic (and probably unmonitored) discharges from these miscellaneous sources cause system upsets, then the sources should be eliminated.
- Increased preventive maintenance (including winterizing efforts).
- Installation of warning devices and alarms. These are equipment items whose installation depends on a management decision.
- Routine sampling and analysis.
- Better supervision of employees. This can mean that an employee has been doing a less-than-adequate job on normal functions or the supervisor who has been too distant from the day-to-day operations needs to become more involved.

The effective O&M practices described above seem to be cost-effective. They are representative of what the steel industry does to correct many of the problems leading to permit excursions. Finally, most of the systems observed for plants visited in this study (which are well-operated) incorporate all of the practices as part of their operating plan.

APPENDIX A

INFORMATION GATHERING FORMS

GENERAL TREATMENT COMPONENT INFORMATION

Type of treatment component:

Design/operating information (see Specific Treatment Component Information attachments):

Influent pollutant concentration (design/long term):

Discharge pollutant concentration (design/long term):

Sources of influent water:

Process (source) production rates and corresponding wastewater flows:

Key parameters monitored:

Types and manufacturers of monitors utilized (e.g., flow meters)

Frequency of monitor calibration:

Warning mechanisms utilized:

No. of operators required:

Level of operator attention required (e.g., continuous, periodic):

Types of logs/records maintained:

Chemical additives used (see Attachment 1):

Flow diagrams available for review:

O&M manual available for review:

Spare equipment available:

Component surge capacity and retention time:

Equipment reliability:

TREATMENT SYSTEM CHECKLIST

Items	Yes	No	Comment
1. Plans/process flow diagrams obtained?			
2. Plant O&M manual available?			
3. Logs/records reviewed? Operating Maintenance			
4. Permit files reviewed?			
5. Discussion with operator(s)?			
6. Discussion with maintenance personnel?			
7. Process area toured?			
8. Attachments completed?			
9. Follow-up required?			

TREATMENT SYSTEM OPERATING INFORMATION

Operating staff (discuss training programs and responsibilities):

System of communication and its effectiveness between process and wastewater treatment operators:

Performance of system components or of the overall system with changing operating conditions:

Range of conditions that still allows optimum or satisfactory performance:

Use of analytical data to maintain or improve the understanding of the wastewater treatment systems as related to meeting the permit:

Repetitive noncompliance instances and corrective actions:

CHEMICAL ADDITIVE INFORMATION - ATTACHMENT 1

Treatment component	Source of wastewater	Type[a]	Chemical additives					
			Brand name	Concentration, ppm		Method of addition	Point of addition	Effectiveness
				Actual	Recommended			

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[a] e.g., corrosion inhibitor, coagulant aid.

Frequency of repetitive problems:

Follow-up to see that the maintenance did correct the problem:

Equipment kept in storehouse:

Equipment that must be ordered:

Types of records maintained:

Types of preventive maintenance performed:

Types of treatment system malfunctions/upsets caused by their own breakdown, by process problems, or by other reasons (see Attachment 2):

Good operating techniques that work for your system:

Performance of continuous monitors for flow, pH, turbidity, etc.:

Indicators used to detect that the treatment system is operating satisfactory or unsatisfactory (e.g., monitors, visual inspection, odor, etc.):

Backup system(s) in case of power failures, control panel problems, etc.:

Methods of analyzing for leaks in noncontact cooling water:

Special operating procedures during abnormal times (e.g., flooding, freezing, equipment failure, maintenance shutdowns):

TREATMENT SYSTEM MAINTENANCE INFORMATION

Maintenance organization (who is responsible for maintaining treatment systems):

List the events that take place from the time a problem is detected until it is corrected (e.g., communication from operators to maintenance, work orders prepared, etc.):

List normal treatment system maintenance:

Major repair items:

Normal repair times:

MALFUNCTIONS/UPSETS - ATTACHMENT 2

Treatment system	Treatment component	Type of malfunction	How detected	Frequency	Cause	Downstream affect	Corrective action	Follow-up action

Equalization Tank

Manufacturer:

Materials of construction:

Age:

Dimensions:

Holding capacity:

Inflow rate and range:

Outflow rate and range:

Inflow concentration range:

Outflow concentration:

Detention time:

Mixing device (if any):

Mixing rpm:

Ammonia Still

Manufacturer:

Model No.:

Age:

No. of plates in free leg:

No. of plates in fixed leg:

Total ammonia concentration of inflow:

Free ammonia concentration of dephlegmator vapor outflow:

Fixed ammonia concentration of outflow:

pH of still inflow:

pH of fixed leg outflow:

Operating temperature and pressure in free leg, lime leg, and fixed leg:

Lime water or caustic soda concentration:

Lime water flow rate:

Liquor inflow rate:

Waste liquor flow rate:

Dephlegmator cooling water flow rate:

Source of cooling water:

Dephlegmator operating temperature and pressure:

Dephlegmator inflow and outflow rate:

Source of steam and temperature:

Clarifier/Thickener

Manufacturer/design firm:

Dimensions:

Holding capacity:

Inlet flow rate:

Outlet flow rate:

Underflow rate:

Detention time:

Settling velocity:

Materials of construction:

Age:

Mechanical or manual cleaning of tank

Mechanical: gpm ________; or scraper velocity, ft/min __________

Manual: frequency __________; time required __________

Quantity of sludge collected per unit time:

Percent solids content of sludge:

Bio-Oxidation (single stage)

Inflow rate:

Capacity of aeration tank:

Dimensions:

Contact time (hydraulic residence time):

Aeration (see page with "aeration" described):

Mechanical or pneumatic stirring:

Settling tank capacity:

Settling tank dimensions:

Settling time:

Percent recycle:

Percent excess sludge:

Sludge age (typical):

Sludge concentration:

Outflow rate:

Mixed liquor solids concentration:

Nutrient addition:

pH of wastewater:

F/M ratio:

Solids retention time:

Influent composition stability:

Alkaline Chlorination

Sources of water being treated:

pH of raw wastewater:

Lime or caustic used for pH control:

pH of adjusted wastewater:

Quantity of wastewater treated daily:

Liquid chlorine (e.g., sodium hypochlorite) or gaseous chlorine applied:

Chlorine dose, mg/ℓ:

Method of chlorine feed control (e.g., electrode measurement of oxidation-reduction potential, ORP):

Residual chlorine concentration, mg/ℓ:

Dechlorination, if applicable

Name reducing agent:

Concentration:

Detention time:

Cooling Tower

Materials of construction:

Conventional or high pH operation:

No. of cycles:

Coolant circulation rate, gpm:

Evaporation rate, gpm (_____% @ _____°F):

Drift loss, gpm:

Total blowdown, gpm:

Makeup, gpm:

Air rate CFM/gpm recirculation rate:

Collection quantity in mud drum per unit time:

Side stream treatment (e.g., silica removal by warm lime softening/clarification, clarifcation for SS removal, filtration, ion exchange, and R.O.):

Specify organic additives or dispersants:

Concentrations of organic additives or dispersants:

Operating range and limits of

Turbidity:
Alkalinity:
pH:
Suspended solids:
Carbonates:
Bicarbonates:
Carbon dioxide:
Silica:
Magnesium:
Calcium:
Chlorides:
COD:
BOD:
NH_3
Dust from air, lbs:
Sulfuric acid feed rate:
Hydrochloric acid feed rate:

Sedimentation Basin

Manufacturer:
Materials of construction:
Age:
Dimensions:
Holding capacity:
Inlet flow rate:
Outlet flow rate:
Underflow rate:
Detention time:
Settling velocity:
Percent removal:
Mechanical or manual cleaning of basin
  Mechanical: gpm __________; or scraper velocity, ft/min __________
  Manual: frequency __________; time required __________

Quantity of sludge collected per unit time:
Percent solids content of sludge:

Settling Lagoon

Dimensions:
Holding capacity:
Inflow rate:
Outflow rate:
Dredging frequency:
Quantity of sludge dredged per unit time:
Detention time:
Solids concentration inflow:
Solids concentration outflow:
Temperature (seasonal minimum/maximum):
Mechanical or diffused-air aeration

Oil Skimmer

Manufacturer:

Model No.:

Automatic or manual operation:

Oil removal rate, gpd:

Operating temperature range:

pH of wastewater:

Oil skimmer protective coating:

Age:

Operating life:

Dimensions of tank:

Capacity of tank:

Inflow rate:

Outflow rate:

Oil and grease concentration inflow:

Oil and grease concentration outflow:

Lime Neutralization (neutralize using lime)

Concentration of lime:

Grade or purity:

Quantity of lime:

pH of influent/effluent:

Quantity of wastewater:

Mixing device:

Mix rpm:

Contact time:

Neutralization vessel

Manufacturer:
Dimensions:
Holding capacity:
Age:
Materials of construction:

Acid Recovery System

Quantity of spent sulfuric acid to undergo recovery:

Free sulfuric acid concentration of spent acid:

Iron concentration of spent acid:

Inflow to crystallizer:

Crystallizer principal of operation (e.g., refrigeration or vacuum):

Quantity of water generated:

Quantity of ferrous sulfate heptahydrate recovered:

Quantity of reusable acid recovered:

Total time required for recovery:

Reusable acid concentration:

"Fresh" acid concentration used in pickling tanks:

Acid Regeneration System

Quantity of spent hydrochloric acid to undergo regeneration:

Free hydrochloric acid concentration of spent acid:

Initial heating step, temperature and time of exposure:

Thermal decomposition step, temperature, and time of exposure:

Quantity of iron oxide generated:

Quantity of water used to reabsorb HCl gas:

Concentration and quantity of regenerated HCl acid:

Total time required for regeneration:

"Fresh" acid concentration used in pickling tanks:

Acid Neutralization (neutralize using acid)

Type of acid:

Concentration of acid:

Quantity of acid:

pH of influent/effluent:

Quantity of wastewater:

Mixing device:

Contact time:

Neutralization vessel

Manufacturer:
Dimensions:
Holding capacity:
Age:
Materials of construction:

Filtration (gravity and pressure)

Manufacturer/design firm:

No. of filter beds: total _________; normally operating _________

Dimensions of filter beds:

Downflow rate, gpm/ft^2: normal operating _________; design maximum _________

Media

Type:

Depth:

Age:

Frequency of change out:

Backwashing

Frequency:

Time required:

Source of water:

Air/water flow rates:

Destination of backwash water:

Automatically or manually controlled:

Pressure just prior to backwash:

Pressure following backwash:

Cascade Rinse System

No. of stages:

Dilution rate, gpm:

Source of water supply:

Capacity of each stage:

Discharge rate, gpm:

Tons of steel rinsed per day:

pH of discharge:

Suspended solids concentration of discharge:

Recycle (general and recycle final cooler)

Percent recycle:

Criteria for blowdown:

Volume of recycle loop, gal.:

Flow rate:

Recycle system materials of construction:

Fume Hood Scrubber (FHS) Recycle

Same as above, plus:

Maximum dissolved solids concentration allowed:

pH of recycle:

Scale Pit

Manufacturer:

Materials of construction:

Age:

Dimensions:

Holding capacity:

Inlet flow rate:

Outlet flow rate:

Dredging frequency:

Method of dredging:

Quantity of dredged material:

Detention time:

Settling velocity:

Percent removal:

Quench Tower

Start quench by remote or manual operation:

Percent average moisture in coke after quench:

No. of stationary sprays and arrangement:

Time of quench:

Application rate, gal/ton:

Source of quench water:

Source of makeup water:

Percent recycle:

Spray density, gpm/ft^2:

Spray pressure, psi:

Coke quenched, tons/day:

Vacuum Filtration

Identify filtration system (e.g., revolving-drum filter):

Volume of wastewater treated per unit time:

Cake-producing capacity, lbs hourly/ft^2 (dry basis):

Volume of sludge liquor generated per unit time:

Percent solids content of sludge cake:

Identify filter medium (e.g., coiled springs or cloth on screening):

Filter speed (peripheral), fpm:

Initial vacuum, in. Hg:

Drying vacuum, in. Hg:

Thickness of sludge cake:

Power requirements, hp/ft^2 of filter area:

Sludge age:

Chemicals used in sludge conditioning:

Drum submergence:

Inclined Plate Separator

Influent suspended solids concentration, mg/ℓ:

Inflow rate, gpm:

Settling area, ft^2:

Effluent suspended solids concentration, mg/ℓ:

Quantity sludge generated per day:

Aeration

Specify type of aeration unit (e.g., turbine, surface, diffused-air):

Turbine aeration

Manufacturer:
Model No.:
Impeller peripheral speed, fps:
Impeller diameter:
Operating compressor horsepower:
Operating rotor horsepower:
No. of submerged impellers:
Air-flow rate:
D/T ratio (diameter of turbine/diameter of aeration tank):
Optimum power split (hp of rotor/hp of compressor):
Tank dimensions:
Shape of tank:
Dissolved oxygen concentration:
Operating temperature:

Diffused-air aeration

Manufacturer:
Model No.:
Horsepower of blower:
Air-flow rate:
No. of aeration units:
Spacing of aeration units:
Efficiency of diffused aeration unit:
Dissolved oxygen concentration:
Operating temperature:
Tank dimensions:

Surface aeration

Manufacturer:
Model No.:
Operating hp:
Air-flow rate:
No. of surface aerators and spacing:
Dissolved oxygen concentration:
Operating temperature:
Tank dimensions: